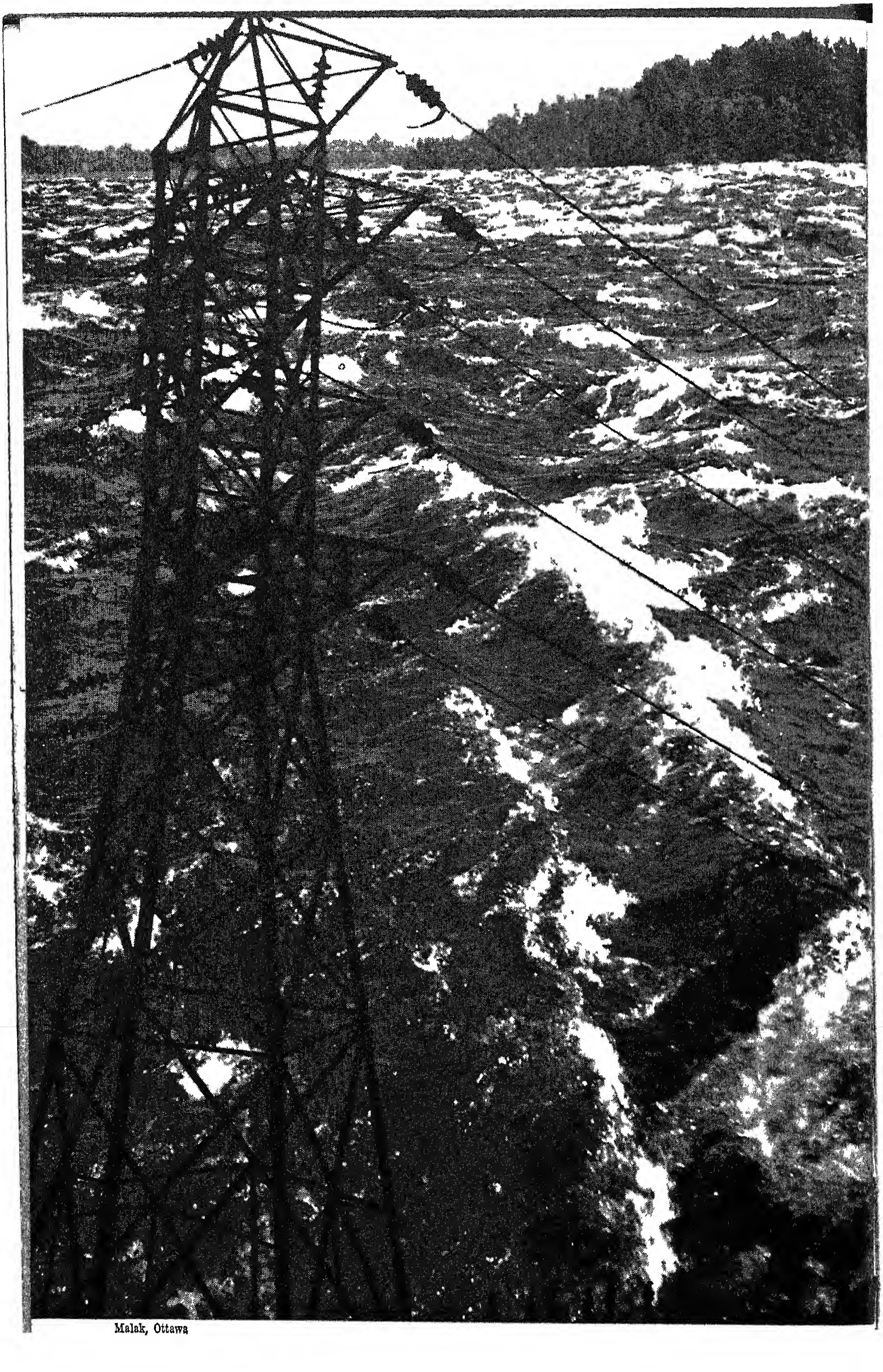

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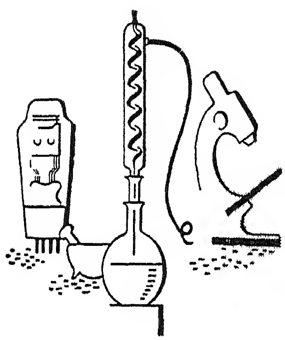
THE BOOK OF
POPULAR SCIENCE



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CONTENTS OF VOLUME IX

ROADS AND ROAD-MAKING

The Avenues of Trade and Travel in Many Times and Lands

NO settled country can reach a high state of prosperity without good and numerous roads. This sweeping statement held true in past ages; it still holds true in spite of the great development of rail and air travel. It is true that the railroad seemed destined at one time to all but supplant the highways that traversed civilized countries. At the turn of the century many thoughtful men feared that the world's greatest roads would fall into disuse and decay because of the ruinous competition of the railroads. But their dire predictions have proved to be laughably inaccurate. We now realize that the railroad caused a great many new roads to come into being as it opened up new areas. In many cases railroads now supplement the busses and trucks and automobiles that travel along the highways. Where there is direct and serious competition, it is likely to be the railroad that will succumb in the struggle.

As for the airplane, it has afforded a providential means of transportation in places where roads are non-existent or few and far between. It has rendered accessible snowbound fastnesses in Canada and Alaska as well as the communities scattered in the steaming jungles of the Amazon or the boundless wastes of the broad Sahara. But it has not affected existing roads in the slightest degree, nor has it caused any appreciable slackening in the rate of growth of new roads. Even with the advent of the helicopter the airplane cannot hope to offer the same flexible and ready sort of transportation as is provided by the automobile, which at one moment threads its way through crowded city streets and at the next speeds along a superhighway. The airplane provides an exceedingly rapid mode of transportation, but the ever increasing congestion of automobile traffic shows that air travel has not had the slightest effect upon travel on our highways.

Roads offer an excellent means of gauging the progress of a community. If a given community has no roads or only poor roads, with no access to a main highway, the chances are that its people will be in an extremely retarded state of social development. The beautiful simplicity of such isolated communities as Oliver Goldsmith depicted in THE DESERTED VILLAGE is apt to have its unfortunate drawbacks, even if the people live in such favorable surroundings as those provided by "sweet Auburn, loveliest village of the plain." It is true that a life of isolation may produce a certain quota of noble and understanding characters, but it is almost certain that the people of the community, taking them by and large, will be narrow-minded and superstitious and tied down by hampering traditions.

The effect of new roads upon a hitherto isolated community

When a highway connects such a community with the vast outside world, the effects are apt to be amazing. Contact with other communities brings new and vital interests. Trade and commerce begin to flourish. The community begins to find new markets for the products of its labor; the importation of new commodities brings about a higher standard of living. The intolerance of the community breaks down as it establishes closer relations with other communities and discovers that strangers can be good people. Its intellectual life quickens as it comes in contact with new ideas. Increased prosperity and higher intellectual standards lead to the building of new schools, new hospitals, new theaters and new concert halls. It becomes increasingly difficult to understand those who long for the "good old days."

The historical division of roads into the few that are very old and the many that are modern — a product of the present age of technical progress — is striking, for it illustrates the long period of industrial and mechanical stagnation between ancient and modern times. The Romans did many things as well as the men of the Middle Ages and the Renaissance, and they did some things — including the construction of roads — much better.

When Hannibal was forced to make a road for his army across the Alps into Italy, in 218 B.C., he could use only the methods invented by the ancient Egyptians. Small rocks were cleared away by hand tools and wedges. The fire-setting system was employed for very large stones. The rock was heated by lighting a fire on it; and when very hot it was suddenly chilled with water, the rapid contraction often causing it to split. It was slow work; and when the road makers were confronted by a granite mass too large to be broken by hand tools or fire and water, they had to twist their path around it.

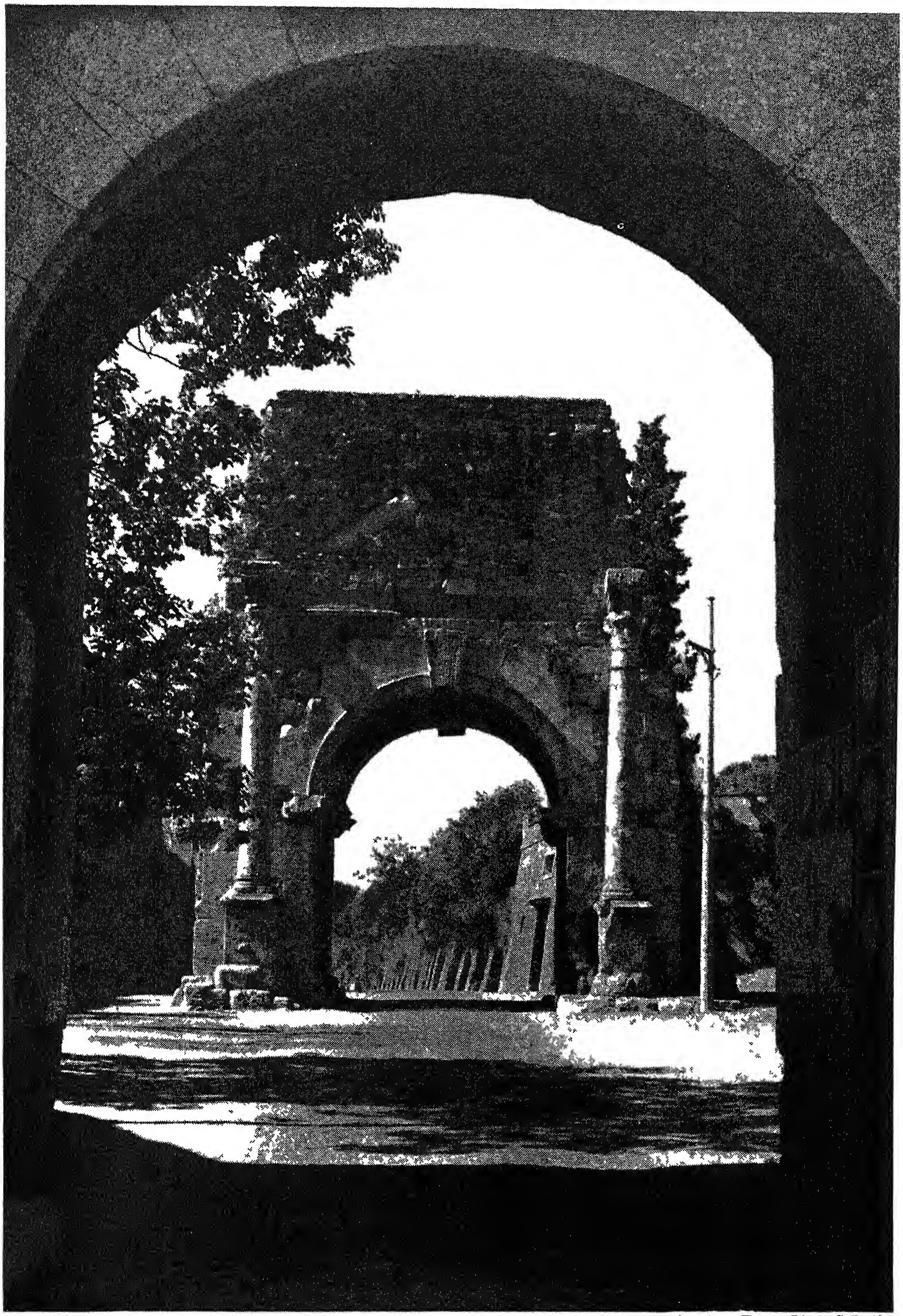
Now all is changed. The making of a modern road is an incident in the dramatic history of the mastery of space and time that has been proceeding so sensationally. It is indeed true that modern road making goes back only about two hundred years. John McAdam was born in 1756, and Thomas Telford in 1757, and with these contemporaries a new era in road construction may be said to have begun. Since their day, road making has transformed the world and made comparisons with other times absurd. Countries that have not built new-type roads are not in the modern age of speedy and comfortable highway travel.

The history of the highway is a story in four chapters. The first concerns the man who walks; the second, the man who rides a horse; the third, the man who uses a wheeled vehicle drawn by animals; the fourth, the man who rides on or in other forms of wheeled conveyances. In modern times, of course, the last-named mode of transportation has become predominant on the roads of civilized countries.

The first roads were tracks, foot paths and trails, designed chiefly to keep the traveler out of wet places. One may still see the pattern in many a winding country road. Perhaps our sentimental attitude toward foot paths, anywhere, is an unwitting reversion to the primitive days when the single-file trail was the only road. Half the charm of the country, whether we wander through the meadows or the woods, or climb the beckoning hills, comes from

Public Roads Administration

Model showing the method of construction of the Appian Way. Careful preparation of the foundation and painstaking shaping and fitting of paving blocks made possible a road that was smooth and endurable.



American Export Lines Collection

Roman arches bend over the Appian Way as it enters Rome from the southeast. This durably constructed highway — once paved with lava blocks — attests to the competence of Roman road builders.

the faint romance of the foot-road. The instinct of the African following his forest track from the coast to the interior, or the Indian of the New World traversing the wood that is trackless to the stranger, or the mountain guide who walks with eyes that trace a way ten miles off, lives in a dim way in almost every man—a scarcely heard racial echo from the primeval world.

Nor is the bridle-path, the next stage in the evolution of the road, deprived of sentiment. One feels it when one stumbles upon the deserted packhorse trail across the Rockies, and pictures instinctively the cavalcades of the vanished years; nay, one even feels it when in the Pyrenees or the Alps short-cuts on the old mule-paths are taken while the tame road, crowded with speeding cars, winds smoothly and slowly below us. The energetic and educated little countries — such as Switzerland and Norway — have fully realized, as more backward countries have not, that the road for wheeled traffic is indispensable; and the mule-path is becoming a romantic inconvenience, that only satisfies the parts of the world still slumbering under semi-civilizations.

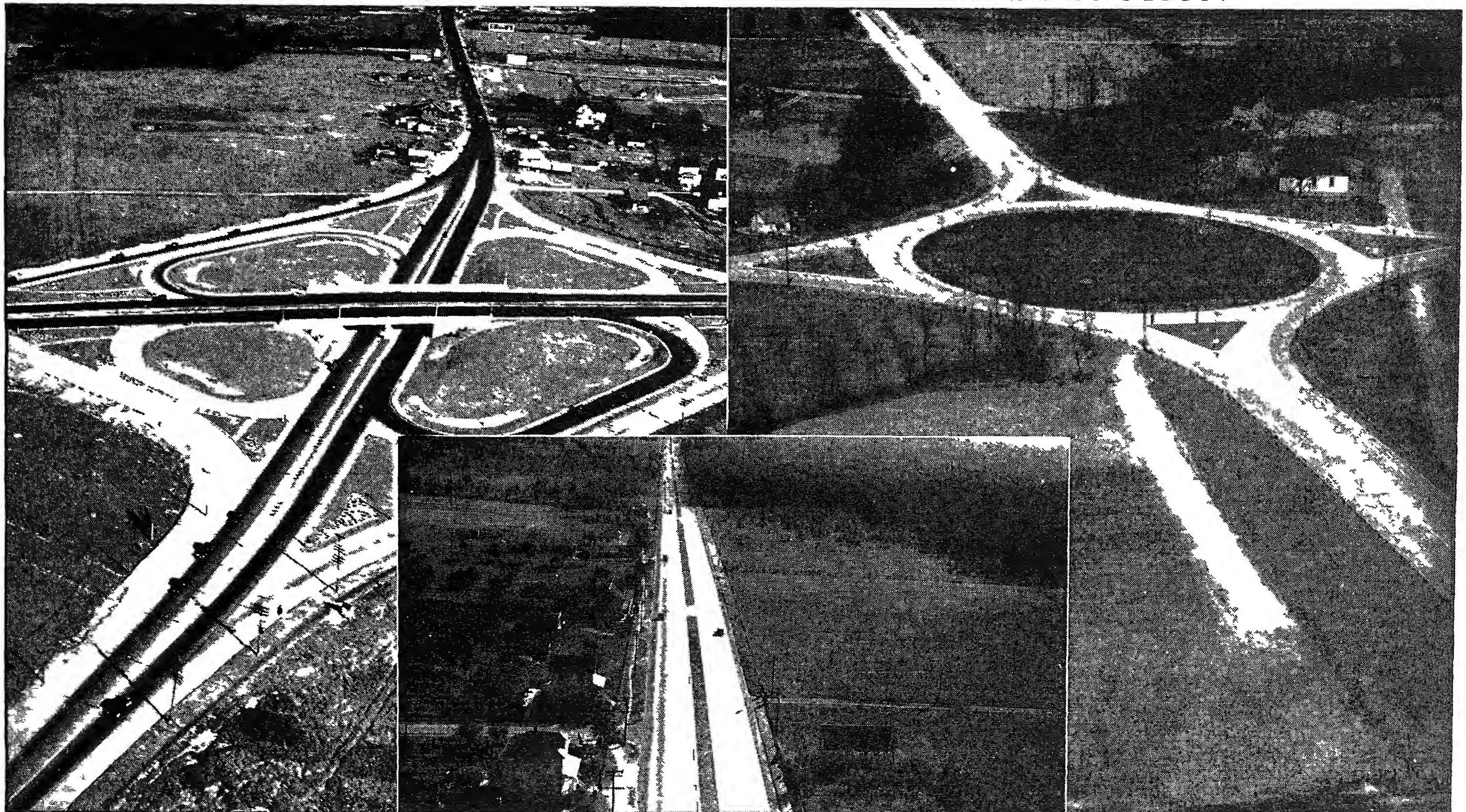
Myers, from Gendreau

PRIMITIVE TRANSPORTATION—CARRYING SUPPLIES TO CHICLE-GATHERERS IN A MEXICAN FOREST

Rather curiously, some of the most prosperous countries on earth were but slowly beginning to understand the true place of the road as late as the first decade of the present century. The most conspicuous examples, perhaps, were the United States and Canada The prosperous agricultural sections of these two countries got on quite well with very few roads worthy of the name, except in the great cities and long-settled districts, until the automobile came along. The automobilist came to realize through bitter experience what roads should be when he began to ride upon them in the newfangled "horseless buggy." He now began to understand why visitors from the Old World to the New were so unfavorably impressed by the makeshift character of so many of the roads, even those in localities of considerable size.

Today, of course, the United States and Canada have an abundance of good roads. The European visitor is apt to be bewildered by the profusion of splendid concrete highways that lead into the metropolis of New York. But why did Americans of a past generation accept their abominable roads with no idea that anything was wrong?

EXAMPLES OF MODERN HIGHWAY CONSTRUCTION

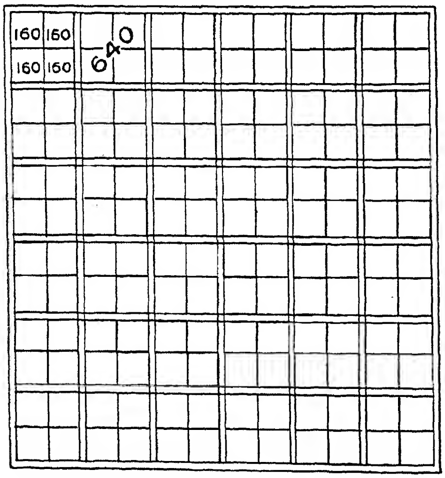


Courtesy N. J. State Highway Commission

SUCH ROADS PROVIDE INCREASED SAFETY AT INTERSECTIONS AND ON THE STRAIGHTAWAY

Left: This clover leaf intersection at Woodbridge, N. J., enables automobiles to enter upon an intersecting road in the direction of traffic, without having crossed any vehicular lanes. Right: A traffic circle on New Jersey Highway No. 35 shows another treatment of the safety problem created by intersecting roads. Center: The 12-foot safety island in the center of N. J. Route 26 (U. S. 1) separates fast traffic moving in opposite directions

The explanation is simple. Until a town or city is sufficiently organized to be able to afford a debt, it does not admit of the need of a road. It suffices to leave a wide strip of the plentiful land, in its natural state, where vehicles may pass. When part of this common passage across the ordinary soil becomes rutted and water-logged, vehicles pass somewhere else on the broad track, until the whole of the site of the future street has assumed the appearance of a plowed field across which heavy wagons have been drawn. Meantime, the inhabitants walk on plank "sidewalks". Presently the city develops till it can borrow money for public improvements, and then road-making begins.



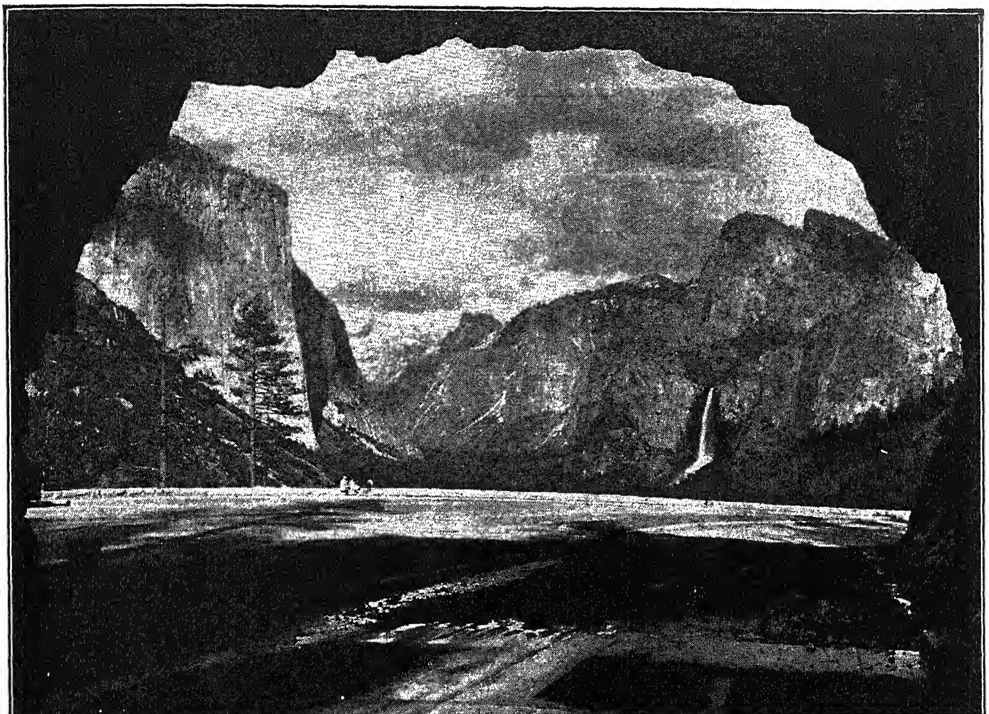
CANADIAN ROADS A MILE APART, AS SURVEYED ON A PRAIRIE TOWNSHIP

The fact is that road-making must always come at a late period in economic organization, and be a coöperative effort.

The problem: When should roads be made? begins with their first need in virgin country and continues after the latest act in town planning is put into force. The whole prairie area of Canada, for example, is surveyed for roads; that is, the country is laid out in townships of six miles by six, with spaces allowed for broad roads, at right angles, every mile, and roads-to-be running north and south and east and west. The accompanying diagram of a township shows the arrangement by which Canada leaves room for its roads of the future—a broad road surrounding each square mile, and a narrower road intersecting each square mile (640 acres), and dividing it into quarter sections of 160 acres — that size being the unit of Canadian farm occupation. Thus, every farm has a possible road on each side of it — open prairie staked out and left for a road.

In English towns where land is the chief expense, the serious problem arises, as estates are laid out for building, shall the roads be first prepared as a prime necessity, or shall the houses be first built, and the roads be allowed to come into being, as avenues with a sound surface, with such slowness or swiftness as the complaints of the inhabitants, or the energy of the local authority in putting pressure on the owners of the adjoining houses and lands, may determine? In Germany the preparatory system prevails, and if houses are to be built satisfactory roads are made beforehand. In England, chance, modified by pressure and agitation, is characteristically preferred, on the ground that capital cannot be spent reasonably on roads until profits are being made on the houses adjoining such roads. In fact, England follows the plan of waiting for the well-made road till press of population makes it inevitable, and, from the point of view of capital, much easier to construct. The more thorough German thinks that, as there must be a road, it is better to have it made beforehand, and so secure sanitary advantages and convenience of transit from the moment the new houses are in use.

The Roman, the first great road-builder, worked with a much clearer idea of the true value of the road. He saw far ahead and knew the folly of holding off from spending as long as possible. He drove his roads to the furthest limits of his empire, and made them to last all time. The result is that some of them have been in use over two thousand years. The Appian Way, known to all visitors to Rome, was begun by Appius Claudius in the year 312 B.C., and so has been serving mankind for more than twenty-two centuries. We know of nothing else made by man that has served him so long.



Courtesy U. S. Bureau of Public Roads

EAST PORTAL, WAWONA TUNNEL, YOSEMITE NATIONAL PARK. BRIDAL VEIL FALLS IN BACKGROUND

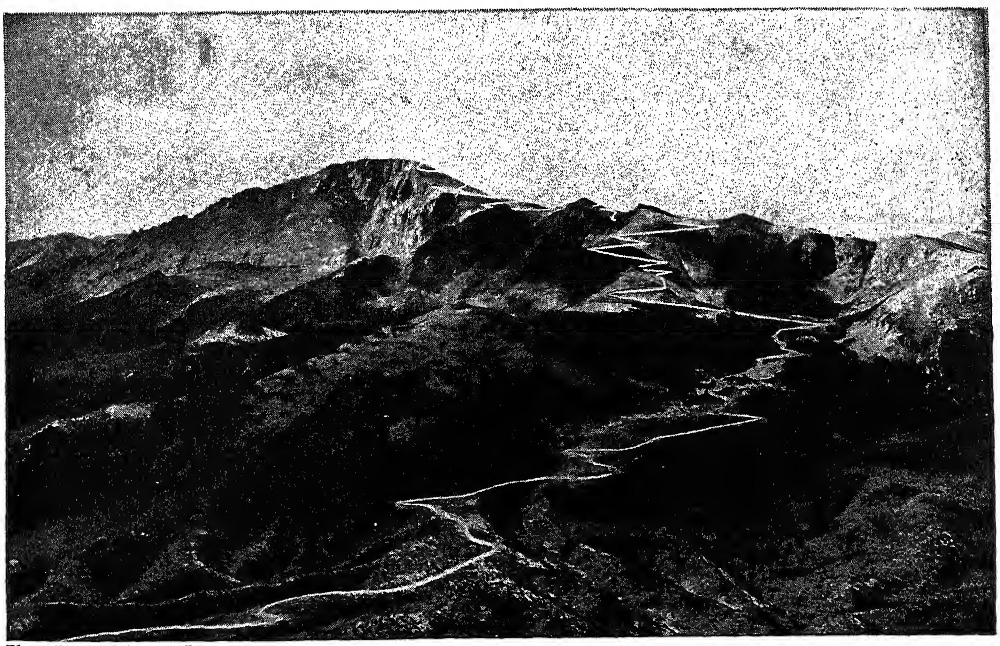
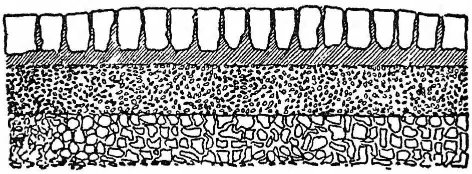


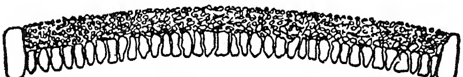
Photo Pikes Peak News Bureau

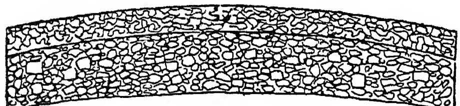
AIRPLANE VIEW OF UPPER SECTION (14,108 FEET ABOVE SEA LEVEL) OF PIKES PEAK AUTO HIGHWAY

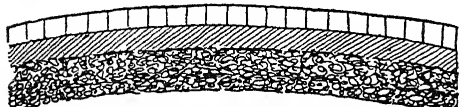
A view of the Appian Way today does not, however, tell us what it was like in the far-off past. Only in two respects does it necessarily preserve its ancient features. Those two are its straightness and narrowness, as indicated by the ruins of the tombs that flank it. Roman roads, though built with such foresight and thoroughness, were always narrow, and only two conveyances could pass at once. The paved part, even on the Appian Way, was but fifteen feet wide, and there was a drainage trench on each side that would make careless driving dangerous. The


Roman road


Seventeenth century road


Eighteenth century road


Modern Macadam road


Wood-paved road

DECLINE AND REVIVAL IN ROAD-MAKING

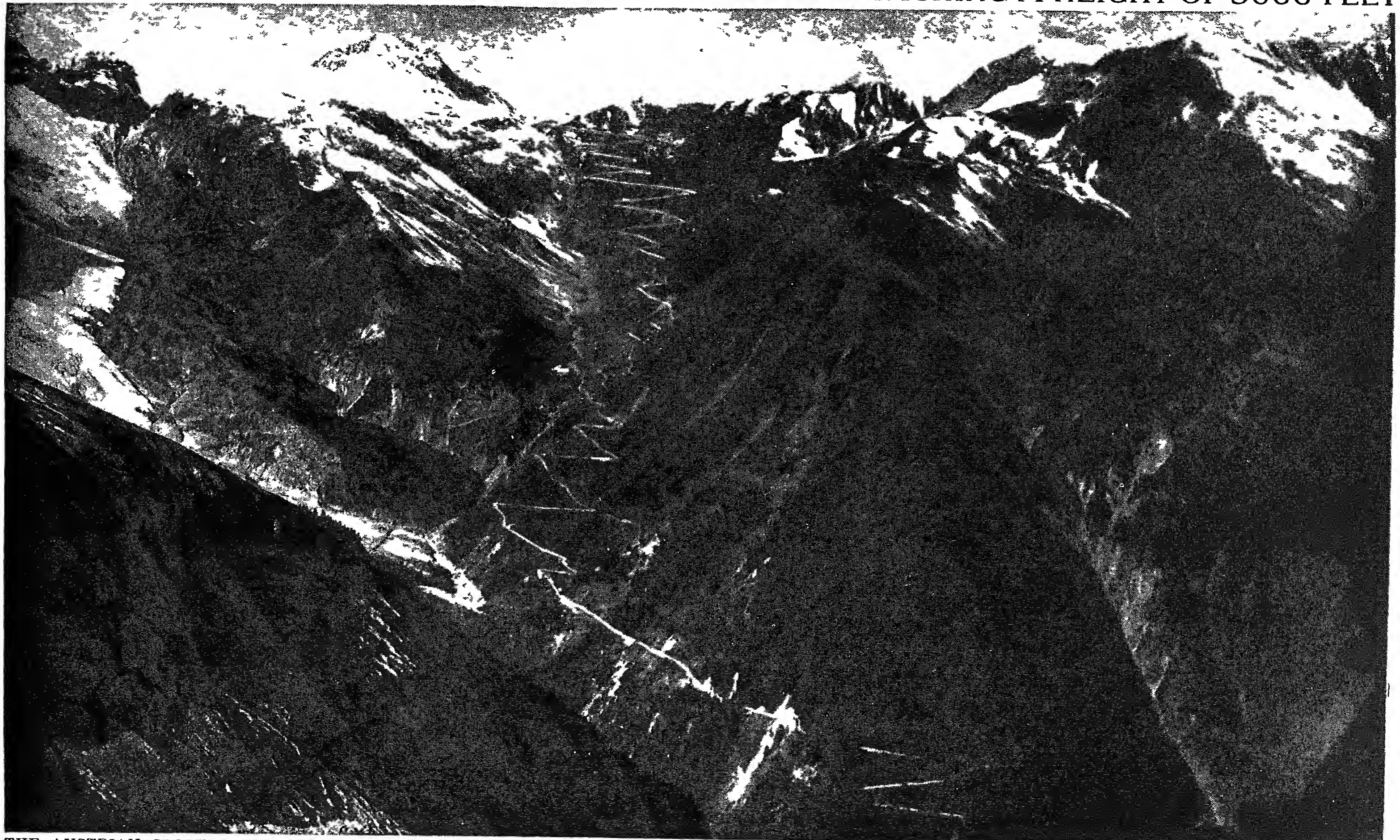
dominant feature of the road, unfamiliar to us now, was the paving — a closely cemented level flooring of flagstones, making an absolutely stone road, that rested on a foundation of prepared stone or concrete, nearly a yard thick. In short, the surface of Roman roads was like the hardest of city pavements of the present day, as smooth and as regular. It was a causeway for vehicles, with narrow walks on either side for foot passengers.

In making it, a trench was cut on each hand, the soft earth removed, and the under layers bedded hard by ramming; then several courses of flat stones were laid in mortar; above this a course of rubble masonry or concrete was added; next, a final layer of concrete, and on the top blocks of stone were carefully fitted and joined. That was the ideal Roman road — really a great smooth causeway of masonry in the neighborhood of the cities, and exceedingly substantial in the country wilds, as may be judged from such remnants as are left after fifteen to seventeen hundred years of waste.

But these good roads — probably never commodious enough for the wants of a considerable population exchanging its goods at great distances — had become a faint tradition in Europe by the middle of the eighteenth century, and every reference one can find to roads at all at that time is a bitter complaint, even in the days when wheeled traffic was a rarity. A journey for many hundreds of years was a genuine adventure; and prayers were needed for all who traveled by land quite as urgently as for those who traveled by sea. So much was this the case that road-making and bridge-building ranked high as religious duties. Indeed, in the twelfth century a religious order, the Pontife Brothers, was founded on the Continent for the purpose of bridge-building. So bad were the English roads in the fourteenth century that the meeting of one of the parliaments of Edward III was postponed specially to await the coming of the members delayed owing to this cause.

Out of this state of chaos England began slowly and experimentally to bungle its way, in the middle of the eighteenth century, by the formation of turnpike trusts. The trusts were established by law to make district roads, which they had power to bar with gates and so levy tolls; and besides these roads the separate parishes could make their own roads, and impose taxes on the inhabitants. A worse system could not well be imagined than that of turnpike trusts, which placed the whole road traffic of the country at the mercy of innumerable little, incompetent bodies; but by sheer pressure of circumstances and dint of complaints the main roads were gradually improved.

THE STELVIO PASS—THE ONLY MAIN ROAD IN EUROPE REACHING A HEIGHT OF 9000 FEET



THE AUSTRIAN SLOPE OF THE STELVIO BEGINS ABOUT 16 MILES FROM THE SUMMIT, AND THE UPPER SEVEN MILES ARE HERE SHOWN, AS SEEN FROM THE FOOTHILLS OF THE ICECLAD ORTLER SPITZ

The originators of the modern road-making systems were two Scotchmen — John Loudon Macadam (1756–1836), and Thomas Telford (1757–1834) Though there have been improvements on their plans, and modern conditions of traffic need fresh modifications of construction and upkeep, these men were the practical poineers of sound roads Some credit is also due Richard Lovell Edgeworth (1744–1817), the father of the novelist Maria, who, previous to Macadam's work, published an essay on the subject He retains his prominence in this connection merely as a theorist, however, not having attained practical success.

Macadam insisted that it was unnecessary to have the elaborate stone foundations which the Romans had used, and that a good, smooth, hard surface could be maintained by spreading, ten or twelve inches deep, stones that had been broken into angular forms of such a size as to pass through a $2\frac{1}{2}$-inch ring The angles, he held, would fit and bind together The weakness of his system was that it necessitated a very uncomfortable period when the broken stone was first placed on the road.

Telford began the construction of roads in the year 1803. His variation from Macadam was that he laid a foundation of large stones, with sufficient spaces

THOMAS TELFORD

Culver Service

JOHN LOUDON MACADAM

between to allow of drainage under the road. Above this rough and strong foundation he placed broken stone, like Macadam, decreasing its size up to the top, so as to avoid the roughness of Macadam's surface. Edgeworth had advised the filling of the interstices with gravel or sharp sand; and now all these plans are combined, with the addition of consolidating the material by using a heavy steam-roller, so that the surface, which has been sanded and watered, is made comparatively smooth at once An up-to-date European road then has a Telford foundation, a Macadam center and a crushed, sprinkled and usually tarred surface.

Before Macadam revolutionized the practice of road construction, there were long periods of distorted ingenuity in spoiling good ideas. Admittedly, for example, a flat road is not a good road. Some slope for drainage is advisable both ways from the crown of the road The common mistake of the road commissioner who only knows a little is to make the crown of the road too high; and this mistake was generally exaggerated in the days before Macadam, with the result that vehicles all sought, and kept, the crown of the road, which in consequence was quickly worn into ruts that became water traps.

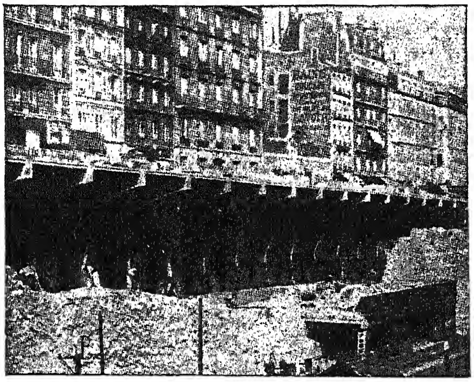
Public Roads Administration

SNOWPLOWS LIKE THE ONE SHOWN ABOVE KEEP OUR HIGHWAYS OPEN THROUGHOUT THE WINTER

The character of the roads of different countries and sections of these countries depends upon many things. Methods of financing, construction management, material available and the tastes of the people all have their influence. In the United States there are at least five different schemes for financing road-building, and, there being no National Road Board as in England, the management is in the hands of the individual state concerned. All countries have been forced to an awakening in matters of road construction and maintenance by the more extensive use of the automobile. Besides demanding more good roads, the motorist has vastly increased the cost of up-keep on the existing highways.

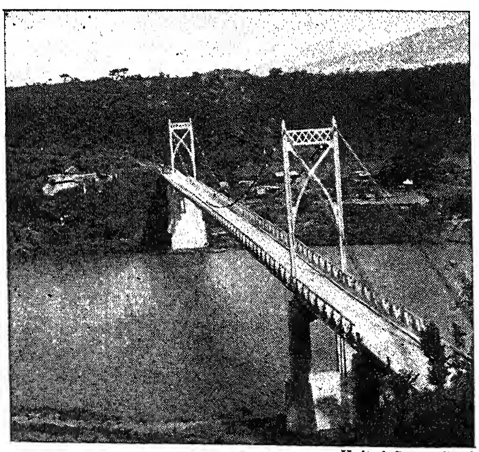
The material for a road in urban districts is chiefly determined by the amount and character of the traffic, and by the gradient. Where heavy vehicles slowly move great weights, as in the neighborhoods of docks and manufacturing plants, cobblestones, granite setts and coarse brick pavements are commonly found, the high construction cost being offset by a long life of usefulness. The gradient should be less than one in forty on account of the slipperiness of the surface during snowy or rainy seasons. On very severe gradients rougher stones such as cobblestones or gritstones must be used. Another objection to stone pavements cannot be overlooked: they are very noisy.

For the business part of towns and cities, wood paving or tar-macadam, varied as asphalt, has become almost universal, because of its cleanliness and noiselessness. The wooden blocks are usually treated with a preservative such as creosote, thus



STREET IN PARIS BUILT ON CONCRETE BRACKETS TO ADMIT OF RAILWAY WIDENING

increasing their length of life. In a busy thoroughfare they may be expected to last ten or twelve years if well laid. The cost of construction may exceed that of the softer varieties of non-slippery stone but the life of the blocks is somewhat longer. Tar-, or water-bound, macadam has a



United States Steel

THE BIG CUSCATLAN BRIDGE, IN EL SALVADOR

much lower initial cost than the wooden block but the expense of up-keep is very heavy and its life relatively short.

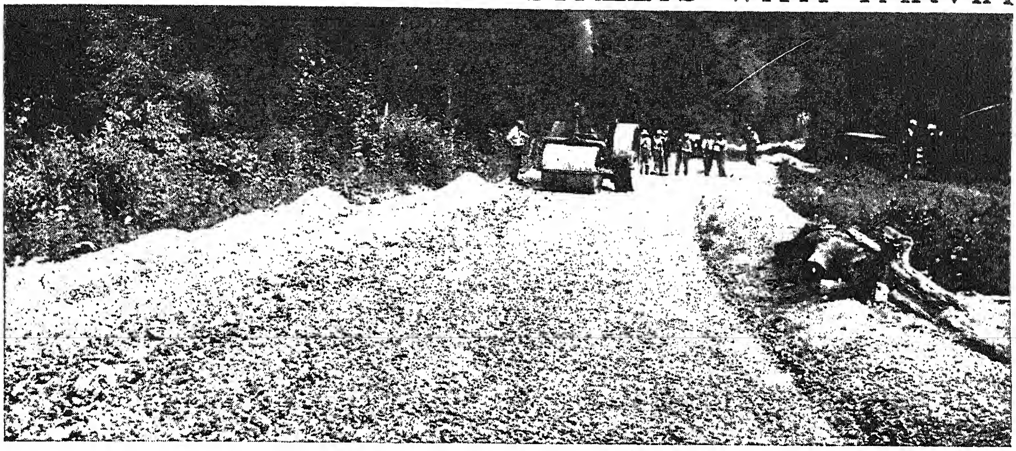
In recent years roads made entirely of concrete have come into extensive use. They give an almost ideal motoring surface. They appear to be durable though when badly worn they are difficult to repair except with some asphaltum mixture, which is also used to fill the cracks that eventually develop in them. In California concrete roads covered with a thin layer of asphaltum compound have been found to be very satisfactory. The famous Columbia River Highway in Oregon is a concrete road.

None the less, the tar-macadam road, or rather a macadam foundation with a bituminous binding on the top, frequently renewed, seems to be a useful type of road, until chemistry invents a dustless surface-preservative that has less stickiness than tar. It has been found that a light dressing of a bituminous mixture will not only make a well-rolled macadam road quite dustless under motor traffic, but that the preservation of the surface of the road more than repays the cost of materials and labor when compared with ordinary renewals; and there is therefore no economic reason why all main roads should not be smooth and practically dustless under motor traffic.

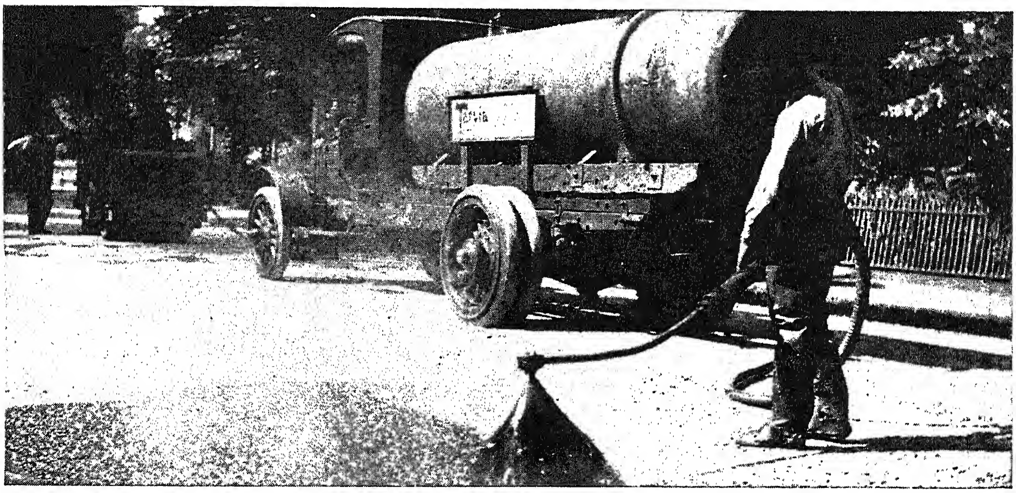
The latest revival of the road in civilized countries began with the bicycle, a vehicle that has played quite a part in the improvement of social and economic conditions, especially in Europe. Then followed the motor car for business and pleasure purposes, at first content with light loads and low speeds, later to carry heavy loads and travel at excessive rates of speed. Eventually heavy trucks and busses came to use many of the roads and caused many complications. For one thing, they were apt to hold up traffic when climbing long and steep hills because they had to shift gears and reduce speed. Besides, they contributed, alarmingly in some cases, to the wear and tear upon the highways. We have not yet solved all the problems brought about by these developments. Yet, on the whole, we have made fine progress in the science of complete and adaptable road-making.

That science is now seen at its best in the two extremes of city life and mountain solitudes. The paving of many of our great cities with wood, asphalt, tar-macadam, dry macadam, gritstone, or granite,

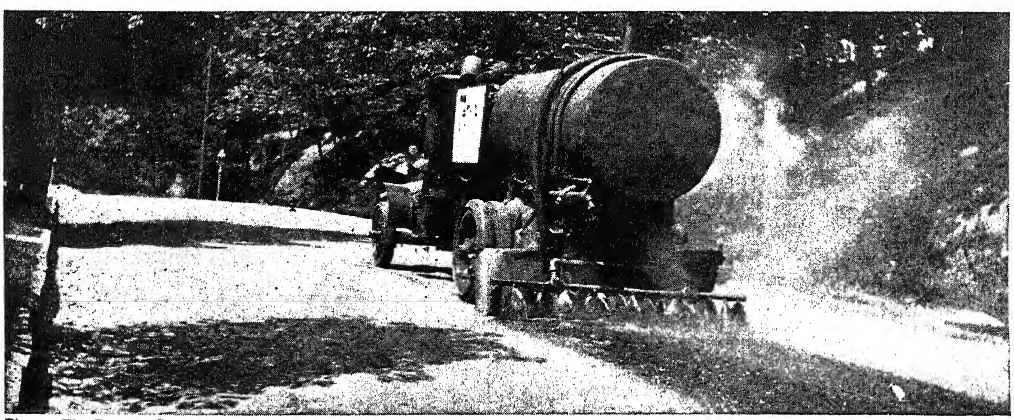
SURFACING ROADS AND STREETS WITH TARVIA



PREPARING THE ROAD-BED: ROLLING THE FIRST COAT



APPLYING TARVIA ON WEARING COURSE BY HAND

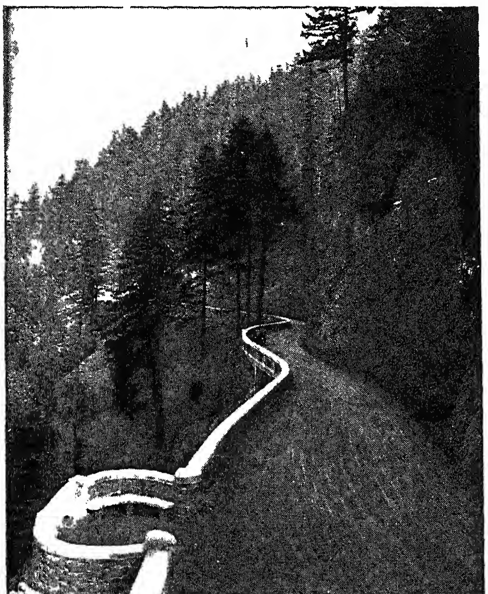


Photos The Barrett Company

A TANK SPRINKLER APPLYING TARVIA TO MACADAM

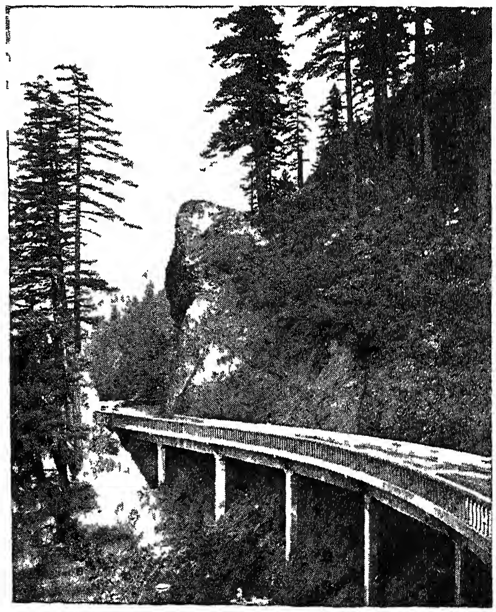
according to the varying requirements of gradient, traffic and cleansing, is an example of masterly engineering and adaptation. At the other extreme are the magnificently engineered roads of the mountainous countries, and such isolated marvels as the motor road up Pikes Peak (14,108 feet) in Colorado. Some of the greatest of the Alpine roads were made, it is true, for military purposes, but they are kept up at heavy cost for peaceful ends, now that the original reason for their construction has disappeared. Thus the great road over the Stelvio Pass, between the valleys of the Adige and the Adda, or Tyrol and Italy, was made by the Austrians as a means of retaining their hold on Venetia. The road, which crosses the snowline at a height of over 9000 feet, costs a great deal to reopen each summer. The repairs, of course, are incessant, and its full service is confined to about three months in the year. From the summit, looking down to Trafoi and the Tyrol, past the noble icy spire of the Ortler Spitz, rising sheer from the opposite side of the valley up which the winding road slowly creeps, seven miles of the zigzagging ascent can be seen. The descent on the Italian side below the summit is much less precipitous, though lower there is repeated tunneling to avoid the dangers of avalanches.

Another great Alpine carriage-road that is highly characteristic is the Splugen Pass on the Italian side, where, by a series of galleries tunneling in and out of the rocks, an almost perpendicular face of cliff is descended. Among mule-trail passes the most noted probably is the Gemmi, between Kandersteg and the Rhone Valley, but the descent into Italy is so steep that riding is forbidden.



Photos Gifford & Prentiss

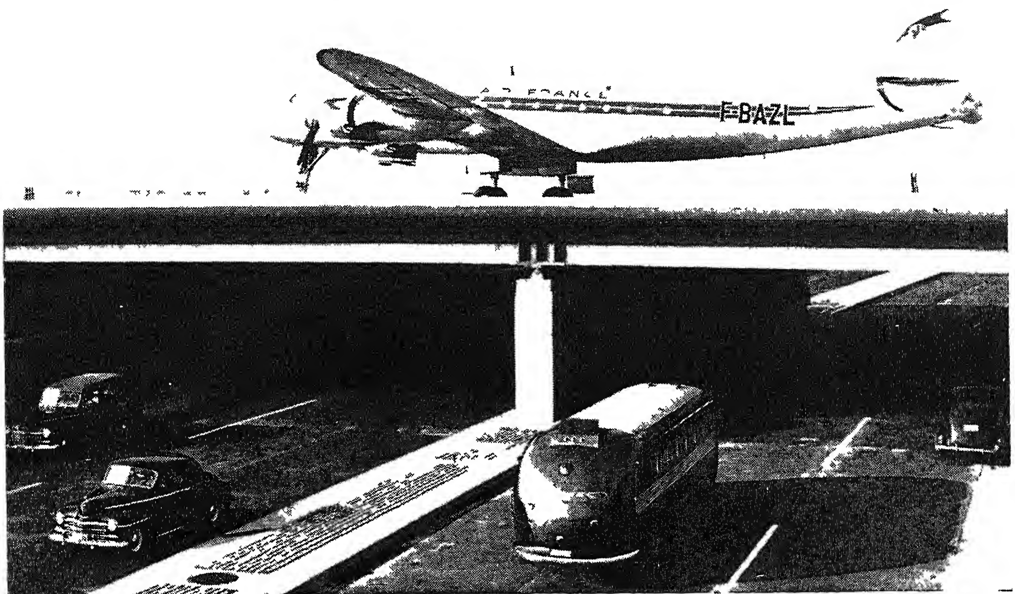
Eagle Crest of Wanna Mountain.



Tooth Rock and half bridge.

ON THE COLUMBIA RIVER HIGHWAY

The aim of engineers in planning a road is to keep it to a gradient of about one in thirty, with a similar cross-gradient, on either side, for drainage purposes. On such a gradient cars have no difficulty in maintaining a good rate of speed. But, of course, in mountain districts that slope often must be exceeded; and in many towns short-distance gradients are found as steep as one in eight or ten. In the case of the Stelvio Pass the rise from the valley of the Adige to the summit of the pass is over 6000 feet, up a continuous ascent of a little over sixteen miles, or an average of about one in fourteen.



Port of New York Authority

This big plane is taxiing across an underpass at the New York International Airport on Long Island

Arnold and Kellogg

An intricate maze of roads guarding one approach to New York City. It helps to make driving more safe.

The United States has not only developed an outstanding system of great highways, but it is also evolving a national policy in this connection. Originally road-making was a function of county authorities and then, as traffic developed, it became something of a state function, cities, however, retaining control of their own streets. Finally the national importance of the question led to federal legislation under which the United States government may assist state road-building with grants of money, but subject to the creation, by the state taking advantage of such aid, of a responsible highway department. This act has greatly stimulated the good roads movement and today practically all of the states have such a department. Naturally, however, this has given rise to contradictory legislation, and in some instances to chaos, in the matter of the division of responsibility. It will take some time to evolve a perfectly logical system of joint federal, state and local control and upkeep. Yet the present system, imperfect as it is, has already accomplished wonders, as we have pointed out. By way of example, let us mention here the Lincoln Highway from New York to San Francisco, the Jefferson Highway from New Orleans to Winnipeg, the Dixie Highway from Chicago to Jacksonville, and the great road which runs from Seattle to San Diego on the Pacific Coast. In some parts of the country the system of state roads has been well developed and most of our large cities can boast of well-paved streets.

Photo Gifford & Prentiss
TUNNEL ON THE COLUMBIA RIVER HIGHWAY

Crandell joint spaces in place.
Pouring gutter expansion joint.
LAYING WOODBLOCK PAVEMENT

SPHERE OF GOVERNMENT ACTIVITY

Delimiting the Field of Political Action and Determining the Policy of Government

HOW SHOULD POWERS BE DISTRIBUTED?

IN the preceding chapter we have referred to the tendency toward ideal conditions in cities. We are now to turn our attention briefly to some of the more general problems of government, particularly as they present themselves in America today, and as the progressive effort at their solution is illustrated in American history and institutions. This task falls naturally into two parts. First of all, we shall consider the precise nature of government (particularly its relationship to the individual) and to what extent such governments as have already been established should undertake to regulate the activities of the citizens. After we have indicated the general lines along which this problem is to be attacked, we shall then consider the second problem of how the government is to go about it to accomplish the particular tasks which are assigned to political organization; that is, the problem of administration.

The starting-point in all thinking about political and social problems is, of course, human wants and the effort to satisfy them. Right at the outset we are met by two opposing theories as to the very mainspring of political organization. The majority of thinkers in this field, beginning with Aristotle, have started from the premise that "man is by nature a political animal". By this is meant that there is innate in every human being a desire to associate and communicate, and perhaps coöperate, with other individuals. These thinkers explain the development of societies largely through the fact that men are inherently social creatures and like to be together and work together. We are thus assimilated to the social or gregarious animals, and the basis of socialization is found in feeling, or in a primary instinct. On the other hand, a great American sociologist, the late Professor Lester F. Ward, sets out from precisely the opposite assumption. He contends that there is no inherent desire to associate, no "instinct of sociability", in the human species. Man is naturally a solitary animal, the largest natural aggregation being that of the small and temporary family group. In this view the evolution of society, and the development of the feeling of sociability itself as well, is due to the possession by man of intelligence, by which he perceives that through association he can much more effectively satisfy other wants. Association or socialization is thus explained as based upon the calculation of advantage to the individual, and not upon an innate disposition, feeling or instinct. Association in itself is supposed not to constitute a desirable end, but to represent a sacrifice, which is undergone for the sake of realizing other ends, purely individual in character, which are more important than the loss suffered through foregoing one's independence.

We need not here pass judgment from the genetic or historical standpoint upon the relative merits of these theories. But whatever may have been the *origin* of human association, many features of the development of political societies in the period of recorded history certainly seem to be better understood in the light of the second of the two theories. Whether or not association gratifies a primitive instinct, it certainly involves the sacrifice, in less or greater degree, of one of the dearest treasures of the human heart, *liberty*.

Thinkers may argue about the innateness of the instinct of sociability, but no one will gainsay the existence in man of the spirit of independence and love of freedom. It is equally clear that association does involve restraint; and the events of history show quite plainly that the extension in the scope and power of organized society has always been granted reluctantly, for the sake of securing obvious and important ends, when not actually forced upon men by irresistible compulsion.

Need of an external authority to enforce contracts actual and tacit

Here, then, we have the conflict of motives. Coöperative activity is the sole means of satisfying innumerable wants, and yet coöperation itself seems to involve restraint and to thwart the desire for individual independence. But this is not the worst of it. Only very limited results can be secured by *voluntary* association and mutual aid. Coöperation, to be effective, must be continuous and at least relatively permanent; the parties having once entered into it cannot be free to change their minds and withdraw again. There must be an external authority to enforce contracts and those quasi-contracts which one tacitly enters into in accepting the customary relations of life; and this means a further loss of freedom. To secure this external authority necessary to even primitive coöperation, the only practicable method yet devised is the establishment of a government having territorial sovereignty. That is, anyone born and continuing to live in a given region is compelled to accept the terms of common life which have been worked out by the people inhabiting it, unless he can induce the established sovereign power itself to change or suspend the laws until he can persuade enough of his fellows to overturn the authority by revolution. Although this means still more compulsion, it is inevitable, especially since the land must be disposed of in some orderly fashion. In practice this has been accomplished in every civilized community by the parceling out of land into private ownership generally continuing in the same families. It hardly takes a Herbert Spencer or a Henry George to point out that men who no longer have the natural right of access to the soil on which all depend for a living are not free but are in virtual bondage. Yet history has shown that such a condition is necessary to any moderate degree of social coöperation; and, freedom or no freedom, it is better than the "war of each against all" so graphically pictured by Hobbes as the alternative to authoritative government and private property.

The first duty of government; "law and order"

All human life, all life higher than that of the "beasts that perish", is social and coöperative, and coöperation involves fixed rules which must be obeyed and will be enforced with penalties sufficient to insure general obedience. The first essential of human life is therefore a code of rules governing the various social relations, and the second essential is a means of enforcing these rules.

In the first place it matters relatively very little what the rules are, so there are rules and so they are obeyed. In various chapters of this discussion we have followed the development of "custom" and means of enforcing it. We have seen that the first sanction was superstition, the first ruler the priest. Primitive religion is in fact almost exclusively political in function, and it has never entirely lost this character; it still covers "duties to fellow men" as well as "duties to God", and includes obedience to the State as one of the principal virtues. It was in the first place merely the means of securing conformity to established usages, and conformity is what we mean by "law and order". In time a differentiation took place. More immediate, visible and tangible means were found for enforcing the more general and fundamental rules of the social life, — what we call the prevention and punishment of crime or misdemeanor, — and religion and the direct pressure of social opinion were left to regulate the more variable and detailed affairs and to form an additional sanction to the recognized law.

The kingly power

The first government was thus a king, not much differentiated from a priest, and remaining in the closest partnership with the elder functionary. It is wrong, however, to think of the first king as an absolute monarch. Theoretically he might be so, but in fact he was about as closely bound by custom as anyone else. He was undoubtedly much more of an executive than a legislator. Here, however, the tendency of change was in the king's favor. One reason for the development of his power was his extreme usefulness in time of war, which is the principal occasion calling for effective coöperation in a primitive people. It should be understood that the primary function of government, the enforcement of law and order, a king may perform exceedingly well. The very evident social utility of obedience to the king, while he keeps in his proper sphere, aided in the growth of the idea, carefully fostered by the king himself of course, that the will of the king is itself the law.

Some practicable provision for changing or making law, as well as for enforcing it, a society must have if it is to progress at all, and for a long time the king may very possibly have performed this office also. However, it naturally was here that he broke down, and his failure as a law-maker gave rise to modern forms and theories of government; probably it even stimulated the first deliberate thinking that men ever did on the question of what a government is for and what it ought to be like. Previously they seem to have accepted the king unquestioningly as the divinely ordained institution he pretended to be.

The law-making function. The idea of a popular will

Laws, as we have seen, were originally not made at all; they were the primeval usages of the people, — customs, which just naturally grew, Topsy-fashion, without thought, plan or purpose. Really, as remarked above, it was a matter of secondary moment what the rules were which governed social relations, but it was absolutely necessary that there be rules.

But in general, usages which survived had to be tolerably suited to a people and its conditions of life. Our own Common Law, inherited from England, is still supposed to go back far beyond all deliberate or authoritative legislation to the customs of the barbarian Germans in the forests of the Rhine and Elbe, though this is apparently in large part a myth. It is questionable how much of it is older than the Norman Conquest of England, and probably most of it could be traced to a "statute" or to the *ipse dixit* of some judge. In a more real sense, perhaps, the Civil Law or Roman Law which forms the basis of European legal systems, goes back to the *jus gentium* or "law of the peoples" which the Roman lawyers claimed to find underlying the varieties of law among the multitudes of their subject nations.

Kingship always breaks down when people realize selfishness in king's mandates

When societies came to move about, to grow, to conquer other groups, or learn new modes of life, usages or laws had in some way to be made to fit new conditions, and growing intelligence also demanded their improvement. Primitive groups no doubt held their customs as eternal and sacred, as ends in themselves and not to be questioned. But it would not be so with the arbitrary orders of a king, probably even if all of these were obviously good. Even so they would lead men to think about the utilitarian bearings of institutions; and if, as soon came to be the case, many of the king's statutes were obviously bad, the subjects would no longer consider the situation tolerable. A people of even limited intelligence will not long regard as sacred mandates which can be seen to aim at the exploitation of themselves in the interest of the ruler's selfish ambitions or personal advantage. And here is where kingship always breaks down. From the standpoint of efficiency in enforcing generally accepted law, it is hardly to be criticized, and it may do tolerably well as a means of meeting new situations. But kings, by bringing their own aims and purposes into conflict with those of the people whom they govern, never fail to

make the people whom they govern conscious of their own wishes, to cause them to reflect on the function of government and to come to see legitimate authority as the means of realizing the popular will. The German Kaiser of pre-World War I days flouted this conception of legitimate authority; for him the State was an "over-being" with a life and purposes of its own to which those of the individual may properly be made subservient. In that country this naive, implicit view of the primitive State was consciously retained and developed into a political theory. In all the more liberal nations, on the contrary, reflection on political questions has invariably led to the other view, that the State is a means only, that its function is to provide the structure of cooperation between individuals in the achievement of their common or mutual ends.

The final step. The theory of democracy. Meaning of political "liberty"

Gradually and as the result of a long struggle, with many ups and downs, the English people, the authors of modern national democracy, got the law-making power into their hands. The result was achieved, as everyone knows, through the control of the people and their representatives over the granting of money to the government. The personal income of the monarchs became less and less adequate to the needs of government and it could not effectively levy and collect taxes without popular support, which had to be secured by adopting policies which the people approved. Thus England gave to the world the theory of democracy, which we have already sketched From the standpoint of efficiency, which means getting things done, monarchy is unexceptionable. But when it comes to the question of the things which the government is to get done, they must be the purposes of the people and not the personal ends of the ruler. The people cannot permit themselves and their resources to be used for ends which are not their own, nor can they allow an accidental hereditary potentate to be the judge of their welfare and the proper means of securing it.

Difficulties in the ways of completely divorcing executive and legislative functions

For the execution of policies after they were popularly determined, the English long retained monarchy. Here the system made its strongest case, and here also democracy was weakest. But the logic of the situation demanded that the people have at least ultimate control over the administration as well as the formulation of law. There cannot be a permanent and complete division of the functions of government, and in all free or democratic nations today the executive as well as the law-making officers are popularly chosen and controlled. In England the king no longer appoints, in anything but a formal sense, the ministers who are the chief executive officers of the government; he is in fact more of a symbol of unity and continuity in the State — like the flag or the great seal — than a government official at all. It is to be noted, however, that experience has proven it unwise to bring the executive branch into as close touch with the people as both expediency and the safeguarding of their interests require in the case of legislation. The best political opinion of today would favor bringing the legislative branch as close to the people as possible or practicable, and keeping the executive as far away as is consistent with securing harmony between the two divisions. Our "Independent Judiciary" is a measure looking to this end, as the Judiciary is really executive or law-enforcing in function although organized in the United States as a coordinate department alongside the Executive and Legislative.

The theory of democracy is thus the recognition that government is an agency for reënforcing the "people's will", which means merely regulating that compulsory coöperation on which all civilization rests along the lines and directing it to the ends which the citizenship desires. It is really the only possible conscious theory of government. We cannot see how one can consistently support the idea of the State as a supergovernment, with purposes that clash with the interests of its citizens.

The Twentieth Century (1895-   ) II

by JUSTUS SCHIFFERES

THE NEW SCIENCE OF MAN

"THE proper study of mankind is man," affirmed the eighteenth-century English poet Alexander Pope: The study of man and society goes back to ancient times. After all, Aristotle was as greatly interested in politics as in biology, in the organization of the courts of Athens as in the life cycle of the crayfish. But the scientific study of man and his society is, comparatively speaking, still in its infancy. In these pages we shall sketch recent developments in such "man sciences" as anthropology and archaeology; we shall also see how paleontology has helped to solve the mysteries that surround man's early history.

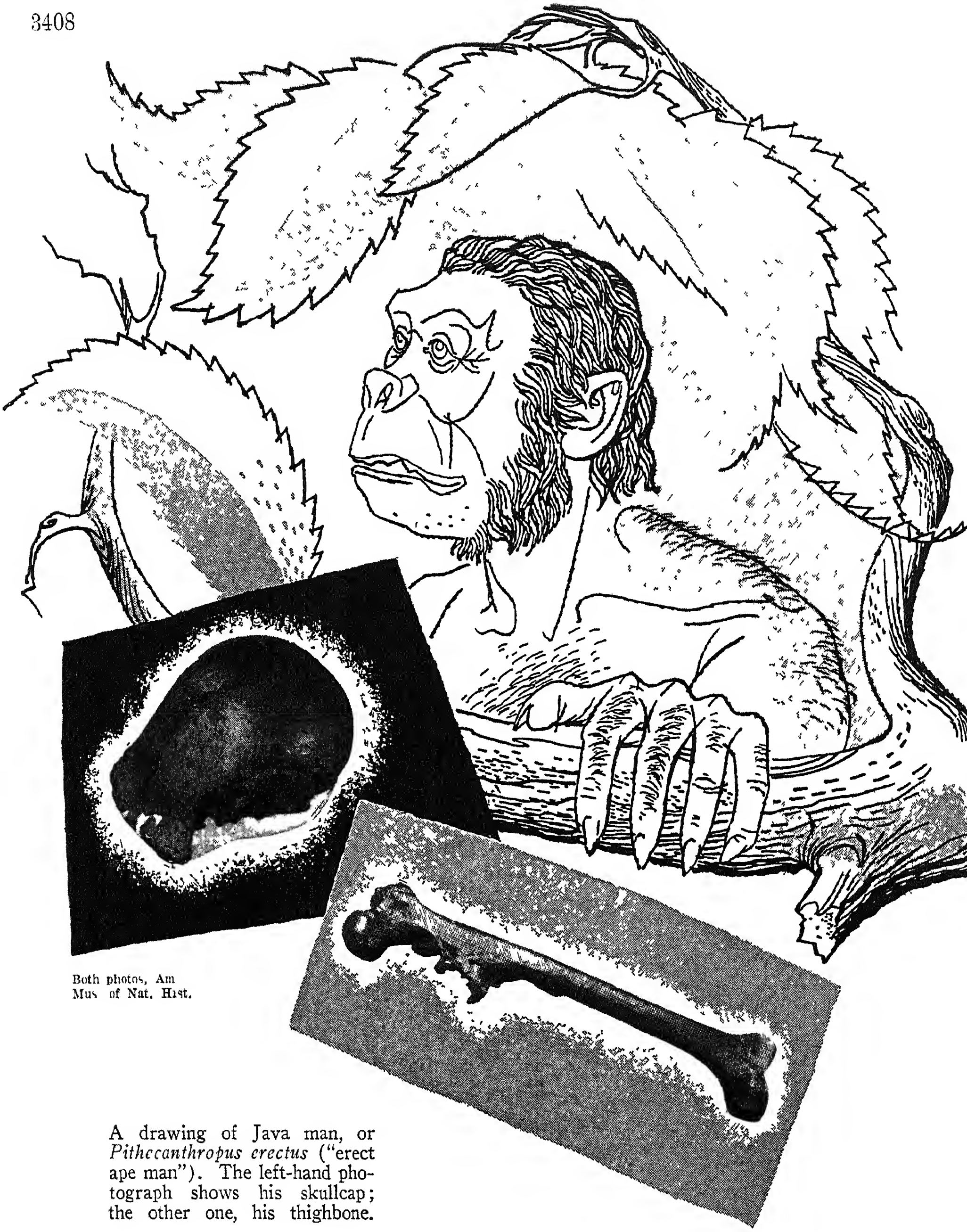
Paleontology is a branch of comparative anatomy; it attempts to reconstruct ancient and extinct forms of living things on the basis of fossil fragments. Anthropology is the study of mankind's physical structure and social relationships. In its examination of these relationships, anthropology extends into other fields of study—sociology, political economy, economics and even history. Archaeology is the science of prehistory; it attempts to reconstruct lost civilizations. In this task it frequently uses as clues articles made by man — artifacts — such as pieces of broken dishes and chipped flints, in much the same way as paleontology uses fossil remains to reconstruct extinct animals.

The doctrine of organic evolution has had great influence upon these sciences and has set a pattern for their study. The procedure has usually been to arrange findings in accordance with a time scale, so that the evolution of one form into another may be followed. Thus we find paleontologists demonstrating how the five-toed horse of the southwestern American desert gradually evolved into a three-toed horse and, eventually, into the hoofed horse of modern times. Similarly, we see archaeologists and historians piling up evidence of the rise and fall of ancient empires — like the Sumerian in Asia Minor — of which written records have given us only a brief account.

The prehistory of man is a fascinating study. When we speak of prehistory, we have in mind the unwritten records of man's sojourn on this planet, earth — his adjustment to its land area and sea spaces, to its changing climates and to its non-human inhabitants. To understand the importance of prehistory, we must bear in mind that recorded history covers something like a hundredth part of the life span of the human race up till now.

The classical anthropologists were for the most part "arm-chair" experts, as the geologists once had been; they based their conclusions on the tales told by travelers and missionaries. About the middle of the nineteenth century, field investigations in anthropology and archaeology began to be taken more seriously. More rational and acceptable conclusions about the prehistory of man and other inhabitants of the globe then became possible.

In his ANTIQUITY OF MAN, published in 1863 — four years after the appearance of Darwin's ORIGIN OF SPECIES — Sir Charles Lyell maintained that man had existed upon the earth at a period much more remote than was commonly believed. In reaching these conclusions, Lyell had certain fossil records to go by. The most



Both photos, Am Mus of Nat. Hist.

A drawing of Java man, or *Pithecanthropus erectus* ("erect ape man"). The left-hand photograph shows his skullcap; the other one, his thighbone.

important of these, perhaps, consisted of a skullcap and certain other bones picked up at Neanderthal, near the German city of Duesseldorf, in 1857. The creature to whom these bones had belonged received the name of Neanderthal man. Later research indicated that this low-browed, shaggy-haired fellow was the predecessor of modern man. Neanderthal man is scientifically known as *Homo,* while modern man is described as *Homo sapiens* (wise man). Neanderthal man lived in the glacial and postglacial stages of Europe, when the great mammals, like the woolly rhinoceros, were still alive but dying out.

In 1891 anthropologists were thrilled by a new find. The Dutch anatomist Eugène Dubois (1858–1941) was digging in

Pliocene deposits on the banks of the Trinity River, in Java, when he came upon the skullcap, leg bone and two molars of what seemed to be either a higher ape or a low form of man. Scientific authorities concluded that this was an ape man, intermediate in structure between the anthropoid apes and the earliest known forms of man. This ape man, or Java man, as he was also called, was given the name of *Pithecanthropus erectus* (erect ape man), and was hailed as the missing link between the higher apes and man. As a matter of fact, the term "missing link" is a misnomer; most scientists think of the evolutionary series as a tree with many branches rather than as a chain with many links.

Another important discovery was made by Charles Dawson at Piltdown, in the county of Essex, England, in 1911. He found part of a skull and the right half of a lower jaw, belonging to what was apparently a primitive sort of man. After studying these remains, Sir Arthur Smith Woodward (1864–1944), a distinguished English paleontologist, decided that the bones were those of a member of a now extinct genus of mankind—an early form that he called *Eoanthropus* (dawn man), because it went back to the dawn of man's history. *Eoanthropus* is also known as the Piltdown man.

Another genus of primitive mankind was discovered in the 1920's. In 1927 a well-preserved fossilized molar was found in cave deposits at Choukoutien, thirty-seven miles northwest of Peking, China. On the basis of this tooth alone, Dr. Davidson Black proposed a new genus and species of prehistoric man — *Sinanthropus pekinensis* (Chinese man of Peking). His boldness was soon vindicated by the discovery (1929–30) in the same deposits of two nearly complete skulls and several jaws and teeth, all as primitive as the molar found in 1927. *Sinanthropus pekinensis* is also known as Peking man.

Of the types of primitive man that we have just named, *Pithecanthropus* and Peking man come first in time; Neanderthal man is the most recent.

Fossil bones are not the only source of our knowledge of prehistoric man; we also rely on such artifacts as tools and flints. In the days when Cuvier and other paleontologists were collecting the fossil remains of extinct animals, it was noticed that stone implements and broken pottery were also found with these fragments. These artifacts and animal bones often formed large heaps, which were later identified as the garbage dumps of prehistoric man. Here he threw the bones of the animals he had eaten as well as the knives and dishes he had broken.

The Frenchman Casimir Picard (1806–41) believed that the tools and flints belonged to the same period as the strata, or layers, in which they were found. He demonstrated that the flaked flint tools discovered in certain layers were quite different from the polished tools that had turned up in other layers.

Picard's compatriot Jacques Boucher de Crèvecoeur de Perthes (1788–1868) came to the same conclusion. The association of the fossil flints with fossil elephants and rhinoceroses showed, he said, that man had lived at the same time as these animals. At first he was laughed to scorn; people called him an "old fool." But the discovery of Neanderthal man in 1857 startled his critics, who became downright apologetic when, a year later, human remains were found associated with the fossil cave bear. By this time, the antiquity of man was beginning to be accepted.

Modern theory holds that man emerged perhaps 250,000, perhaps 500,000, years ago, in the Old Stone Age. It is thought that *Pithecanthropus erectus*, Peking man and dawn man flourished, though not at the same time, during this period.

An interesting and fairly complete reconstruction of the Old Stone Age was provided in 1915 by a Connecticut-born American, Henry Fairfield Osborn (1857–1935). Osborn was a professor of zoology at Columbia University (from 1890) and a curator at the American Museum of Natural History in New York City (from 1891). He was primarily a paleontologist — the author of a classic work, THE AGE OF MAMMALS (1910).

But he took into account not only the evidence of fossil bones but also that supplied by artifacts. He turned, in time, from the task of rebuilding extinct animals to that of reconstructing lost periods in man's history. In his MEN OF THE OLD STONE AGE (1915), he has told a fascinating story of a long vanished era.

Neanderthal man (*Homo*) appeared at the end of the Old Stone Age, according to modern belief. He lived perhaps 25,000, perhaps 50,000, years ago. About 10,000 years ago the New Stone Age began; by that time *Homo sapiens* was on earth. Thereafter followed, in relatively short order (when we consider the whole time span), the Bronze Age, the Early Iron Age, the Classical Age (of Greece and Rome), the Middle Ages, the Renaissance, the New Iron Age (eighteenth century), the Mechanical Age (nineteenth century), the Electrical Age, the Air Age and the Atomic Age. These periods merged into one another and sometimes existed side by side. Thus we of the twentieth century are living at one and the same time in the Mechanical Age, the Electrical Age, the Air Age and the Atomic Age.

The bones and skulls of prehistoric men were carefully measured and analyzed by anthropologists. One of the early methods, developed by Anders Retzius (1796–1860) toward the year 1840, consisted of measuring the size and shape of skulls and thus arriving at what was called the cephalic index (from the Greek *cephalos,* meaning "head"). This represented the skull breadth times 100 divided by the skull length.

The cephalic index was later used extensively in classifying the so-called races of mankind. Thus humans were classified as long-headed (dolichocephalic), short-headed (brachycephalic) and in-between (mesocephalic). Likenesses and dissimilarities in language formed another measuring stick in the classification of mankind; so did such physical characteristics as the color of the skin and the texture of the hair. A great deal of nonsense has been written about the races of mankind: the Nazis, for example, used such misinformation to further their theories of "Aryan supremacy."

The races of mankind really merge into one another. If science has demonstrated anything at all, it has made more and more manifest the ancient ethical truth: "All men are brothers. One Father has made us all."

The study of the physical traits of prehistoric man was carried on in the twentieth century by a number of anthropologists, among whom perhaps the most distinguished were the Englishman Keith and the American Hrdlicka. Sir Arthur Keith (born in 1866) was Fullerian professor of physiology at the Royal Institution from 1917 to 1923, and rector of the University of Aberdeen from 1930 to 1933. He did remarkable work in the reconstruction of prehistoric man from fragments or fossil remains and wrote a number of im-

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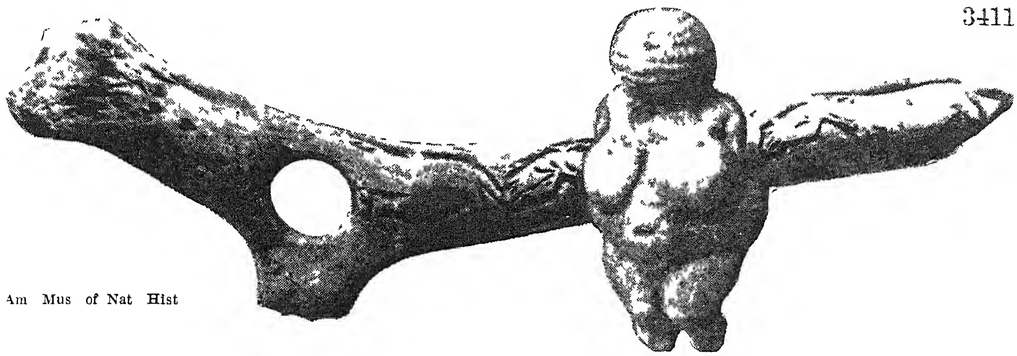
NEANDERTHAL MAN PEKING MAN PILTDOWN MAN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The engraving and sculpture shown above are fine examples of Old Stone Age art in Europe.

portant books, including ANCIENT TYPES OF MAN (1911), THE HUMAN BODY (1912) and THE ANTIQUITY OF MAN (1915). Sir Arthur was a phrenologist — that is, he believed that the shape of the skull gave a clue to an individual's mental faculties. However, unlike many unscientific phrenologists, he made no extravagant claims. "The day will possibly come," he said, "when we can decipher the parts of the brain in the living head, and ascribe with certainty the functional significance to be attached to them; but certainly that day is far off."

Bohemian-born Ales Hrdlicka (1869–1943) came to the United States as a young man and took part in expeditions (1899–1903) sponsored by the American Museum of Natural History. He made a great reputation for himself on the staff of the National Museum, in Washington, D. C.; as founder and editor (1918) of THE AMERICAN JOURNAL OF PHYSICAL ANTHROPOLOGY; and for his work in anthropometry (measurement of man). Hrdlicka's scientific investigations of fossil remains bearing upon the origin and development of man carried him all over the world. He maintained that, generally speaking, there is no relationship between intelligence and the size and shape of the skull; this belief ran counter, of course, to the views of Sir Arthur Keith. Hrdlicka was a strong supporter of the theory that the American Indians are of Asiatic origin.

Modern anthropology has contributed greatly to our knowledge of the origin and evolution of human society. The great Aristotle was interested in these problems; he classified man as a social animal — midway between beasts and gods. This Greek idea is paralleled in Jewish and Christian theology. It is expressed in the words of the Psalmist that man has been created "a little lower than the angels, with dominion over the beasts of the field."

The scientific study of prehistoric society

The scientific study of prehistoric society goes back to the late nineteenth century. It owes much to the geological theories of Hutton and Lyell. As we have seen, they had maintained that ancient geological changes were brought about by factors that are still operating. Taking a leaf from these geologists' book, a number of anthropologists came to believe that the prehistory of the human race and of its institutions might best be understood by observing existing primitive societies. This notion sent social scientists scurrying to Australia, to the islands of the Far Pacific and to the heart of Africa. The first workers in this field had depended a great deal upon the diaries and the reports of other people — travelers and missionaries; now, workers went to see for themselves and lived among primitive peoples.

The publication of THE GOLDEN BOUGH by James George (later Sir George) Frazer (1854–1941) greatly influenced the development of social anthropology. The work was originally published in two volumes in 1890; by 1915 it had been expanded to twelve volumes. It

described primitive cults, myths and rites It drew its information from a variety of scattered sources, some reliable and others not so trustworthy. It was a case book, which utilized archaeological inscriptions, ancient and medieval historians, modern travelers, missionaries and anthropologists.

A key concept in the study of society is that of folkways. It was presented in 1905 in a brilliant book — FOLKWAYS, OR A STUDY OF THE SOCIOLOGICAL IMPORTANCE OF USAGES, MANNERS, CUSTOMS, MORES AND MORALS — by William Graham Sumner (1840–1910), professor of political and social science at Yale University.

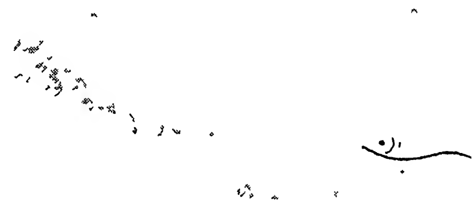
Born in Paterson, New Jersey, trained in sociology and economics, Sumner was ordained a deacon of the Protestant Episcopal Church in 1867 and a priest two years later. Then, in 1872, at a time when the enthusiasm for Darwinism was at its height, he forsook the formal priesthood to become a professor at Yale, where he remained until he died. He was noted as an inspiring teacher and a brilliant lecturer; his grateful students formed a Sumner Society in his honor in order to spread his ideas.

An explanation of the term "folkways"

The term "folkways" simply describes the ways in which folks — modern or primitive people — act and react as they go about the everyday business of living. They try to seek pleasure and to avoid pain. Experience teaches every individual that some ways of doing things are less painful than others; therefore the pleasanter way — in the long run — becomes the habitual way. Eventually the individual believes (often falsely) that it is the only way.

After the people of a tribe have been practicing folkways for a long time, they become convinced that these particular ways of doing things are indispensable to the welfare of the tribe as a whole. If things are done differently, they fear, calamity will result. When this fear for the welfare of society has cast its spell over folkways, they become mores — fixed customs — that have the force of law. Violation of mores becomes a crime against society; it becomes taboo (forbidden). The word "taboo" is of Tongan origin; it is one of the few words that English has taken over from the Polynesian languages.

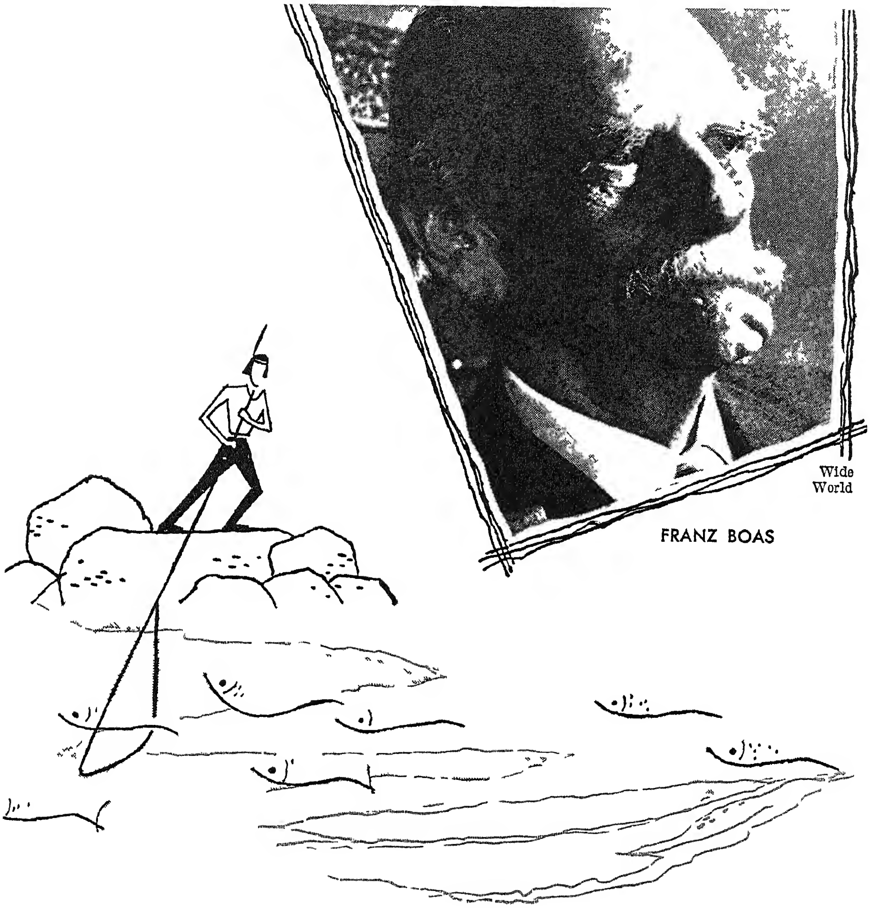
Sumner's pupil Albert G. Keller (born in 1874), who became a professor of the science of society at Yale, carried on his master's teachings. Keller believed that human institutions developed through folkways and mores. He believed that they represent the basic need of men to make the proper adjustment to the land (and sea) areas of the globe, which are at the



same time a dwelling place and a challenge. He taught that all human institutions — government, property, marriage, agriculture, industry and all the rest — have arisen from four basic drives or needs — hunger, sex, ghost-fear and vanity.

The American anthropologist Franz Boas (1858–1942) made an effort to penetrate and understand the mind of primitive man living in society. Born in Westphalia, Germany, in 1858, he came to America as a young man. For over forty years — both on expeditions and on vacations — he studied the culture of the salmon-eating Kwakiutl Indians and other tribes on the northwest coast of North America; he also took part in expeditions to Mexico and Puerto Rico. He was especially interested in considering cultures, whether primitive or modern, as a whole.

Boas was an outstanding authority on the anthropometry and linguistics of North American Indian tribes. He was professor of anthropology at Columbia University from 1899; like his colleague,



FRANZ BOAS

Osborn, he was likewise a curator at the American Museum of Natural History.

Boas' student Ruth Benedict (1887–1948) also made a deep study of primitive societies. Born in New York, she attended Vassar College, where she was graduated in 1909. She taught English for some years and distinguished herself as a poetess In 1919 she began the study of anthropology at Columbia University under Professor Boas. After taking the Ph.D. degree, she became, next to Boas, the leading figure in the Columbia anthropology department. She supplemented her teaching with extensive field experience, living in turn among the Pueblo, Mission, Apache, Pima and Blackfoot Indians. In two important books — PATTERNS OF CULTURE (1934) and RACE: SCIENCE AND POLITICS (1940) — she stressed Boas' idea of the totality of culture. She also pointed out that primitive peoples sometimes are guided by a single dominant attitude: thus, pride of wealth is all-powerful among the Kwakiutls.

Franz Boas studied the culture of the Kwakiutl Indians Above a Kwakiutl fisherman; at the right: a Kwakiutl puppet.

Margaret Mead (born in 1901) also contributed much to the study of primitive peoples. An assistant curator of ethnology at the American Museum of Modern History, from 1926, she did most of her field work in the South Sea islands, particularly New Guinea, Bali and Samoa. She was chiefly interested in the problems of temperament and sex in primitive societies. She wanted to know how young people grew up and got married in New Guinea, how they "came of age" in Samoa. Her work has helped us arrive at a greater understanding of modern adolescents.

Left: a Balinese wood carver; below: Balinese dancers.

Palmer Pictures

The English physiologist and anthropologist William Halse Rivers (1864–1922) wrote a History of Melanesian Society in two volumes (1914) after taking part in an expedition to Melanesia in 1908. He made the point that the apparent development of independent cultures, with all their specialized arts (for example, the embalming of the dead) came about through the intermingling of peoples. Rivers, who was the founder of the Cambridge school of experimental psychology, was one of the first men to link up anthropology and psychology; he tried to trace the connection between instinct and the unconscious mind.

Though history is not a science, the study of prehistory — archaeology — requires a certain amount of scientific apparatus and awareness. In the past it also required much leisure time and money. It remained, until very recent times, the hobby of wealthy amateurs, who spent vast sums on archaeological research.

The amateur who did most to advance the science of archaeology in the nineteenth century was a German businessman, Heinrich Schliemann (1822–90). He was born in Mecklenburg, the son of a poor country parson. His father told him the story of ancient Troy and of the ten-year war between the Trojans and the Greeks. The lad was fascinated, and vowed that he would one day "find Troy."

Knowing that this search would take money, he determined to make himself independently wealthy. After serving as representative for an Amsterdam firm in St. Petersburg (now Leningrad), Russia, he embarked in the indigo trade. He happened to be in California in 1850, when it was admitted to the Union; he thus automatically acquired American citizenship, which he retained to the end of his life. Schliemann made his fortune at last at the time of the Crimean War, chiefly as a military contractor. Thereafter he traveled widely, visiting Tunisia, India, China and Japan. At the same time he acquired a knowledge of seven or eight languages, including ancient and modern Greek.

In the year 1868 he went to Greece and began a careful study of the sites mentioned in the poems of Homer. Then he set off for Asia Minor to examine what was believed to be the site of ancient Troy. Wasting no time in preliminary digging, he had his workmen thrust a trench quickly into the very base of the Trojan hill. As his trenches and side trenches multiplied, Schliemann picked up beautiful statues, costly jewelry and ornamented vases. To his astonishment, the patterns on the vases turned out to be quite different from anything described in Homer.

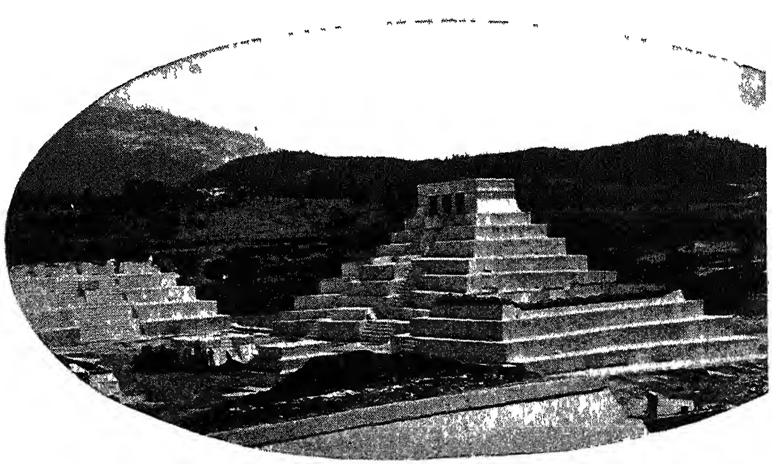
He soon realized that he had dug right through the Troy of which Homer had sung and that he had come upon a Troy at least a thousand years older! In fact, three civilizations lay buried under the Trojan hill. At the top was the Homeric city, which he had missed in the first excavations; at the bottom was a prehistoric city, going back to the New Stone Age and characterized by crude pottery and polished stone hammers. In between was what has been called the Aegean city. It represented a civilization that flourished in preclassical times.

Another city explored by Schliemann — Mycenae — also went back to the preclassical period of Greek history. Other sites in Greece — among them, Orchomenus and Tiryns — and Asia Minor were dug up under Schliemann's direction. Before death ended his career as a digger and writer, he had made the world aware of its archaeological treasures.

The serious study of archaeology in the later nineteenth century and in the twentieth century was immensely benefited by advances in other sciences, which made the identification and the dating of prehistoric events much more accurate. To be a modern archaeologist, it is necessary to be proficient in a number of scientific fields. Thus, to solve the mysteries surrounding the early life of the American Indians, it has been necessary to turn to geology, botany, physics, mathematics and other scientific disciplines. Meteorologists have studied the climates in which prehistoric men lived and thrived. Aerial photography has revealed the location of archaeological sites and important ruins in regions never before mapped; the lost Mayan civilization of Guatemala was revealed in this way.

The application of tree-ring methods of establishing chronology was introduced by Andrew Ellicott Douglass in the early 1900's. Tree rings — which you can see in a cut log or a stump — indicate the age of a tree. By cutting through the timbers used in ancient Indian ruins in the American Southwest and counting the tree rings, it is possible to tell approximately the age of the buildings in which the timbers were found.

Another scientific method for establishing dates is the use of statistical methods in analyzing the petroglyphs — carvings and paintings in rock — of prehistoric man. In Europe the walls of caves in Altamira, Spain, Font-de-Gaume, France, and



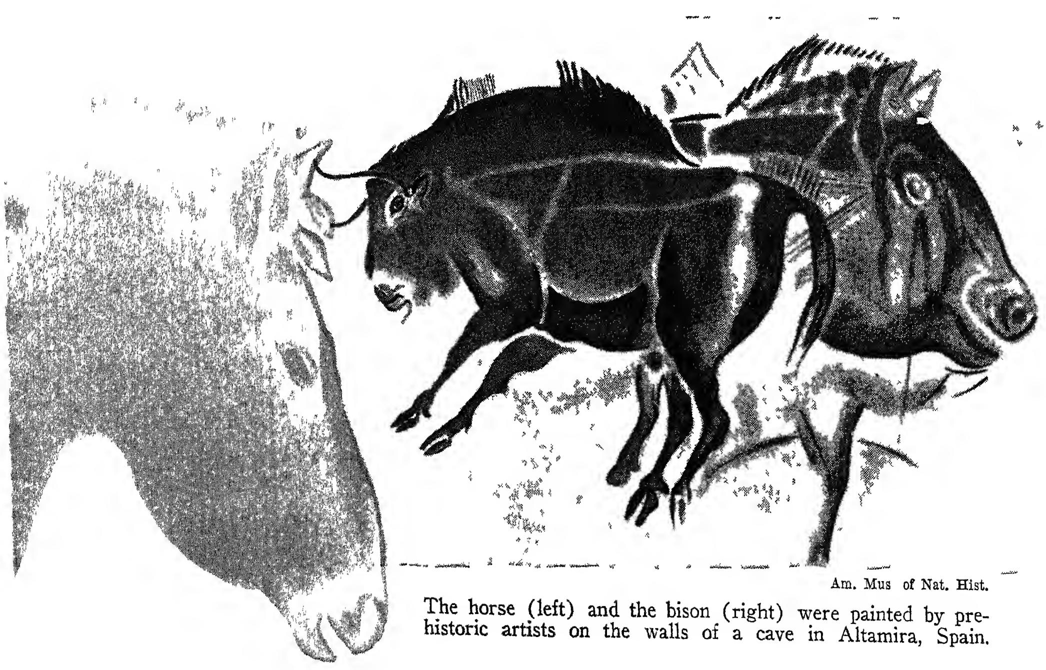
An outstanding example of Mayan architecture: a pyramid in Guatemala.
United Fruit Co.

other places have been found covered with paintings executed in the Old Stone Age. The materials used in making these paintings were simple mineral colors; they were applied to shallow incisions carved out in the smooth surface of the walls. Petroglyphs have also been found in great profusion in North America, often on the walls of canyons or on the boulders of rivers. For a long time, archaeologists neglected these rude specimens of prehistoric art. Yet it gradually became apparent that petroglyphs of different designs were intimately linked with primitive cultures existing in different periods.

After World War II, a new and more accurate method of dating paleontological and archaeological materials was developed. This method depends on the presence of radioisotopes, especially radiocarbon (C^{14}), whose half life — 5568 ± 30 years — is known. (The number 5568 ± 30 lies within the range $5568 + 30$, or 5598, and $5568 - 30$, or 5538.) Thus, for example, we know by radiocarbon dating that certain pine cones picked up in Cuba are over 30,000 years old and that certain parts of a Peruvian Temple of the Sun were (in 1952) 444 ± 25 years old; hence, that the temple dates from the days of the Incas.

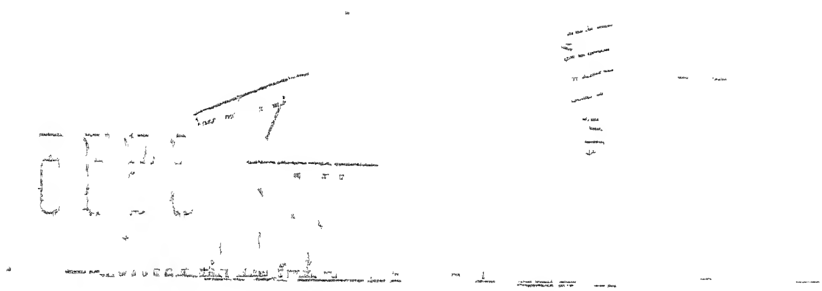
Among the American archaeologists who made a careful study of the petroglyphs were A. L. Kroeber, Julian Steward, of the University of California, and R. L. Tatum, of the United States Naval Academy at Annapolis. Steward drew up a system of fifty typical petroglyph designs; he applied them in the 1930's to the study of different archaeological sites in California. Later Tatum undertook to analyze Steward's material by the application of formal statistical methods. By this means it became possible — in California and elsewhere — to define the limits of cultural areas and, in some cases, to date them.

Archaeology is an unusual science in one respect, at least, in that the scientist is given but one chance. As Tatum has said, "The story of man's past is written as though upon ancient parchment which crumbles when it is exposed to the air. One careless excavation . . . and the knowledge of that specific site is lost forever . . . Year after year archaeologists have seen thousands of pages of history torn to bits for the price of a pretty piece of pottery or a shiny bracelet."



Am. Mus of Nat. Hist.

The horse (left) and the bison (right) were painted by prehistoric artists on the walls of a cave in Altamira, Spain.



MODERN TRIUMPHS OF MEDICINE

The art and science of medicine made more progress in saving human lives in the first half of the twentieth century than in all the earlier history — and prehistory — of man. Advances were made in every branch of medicine — in internal medicine, surgery, gynecology and obstetrics (diseases of women and problems of childbirth), pediatrics (the care of children), dermatology (the study of skin disease), geriatrics (the study of the diseases of the aged), industrial medicine, aviation medicine and preventive medicine, to name only a few. Medical education improved vastly throughout the world, and especially in the United States after the publication of a famous Carnegie Report on Medical Schools by Abraham Flexner in 1910.

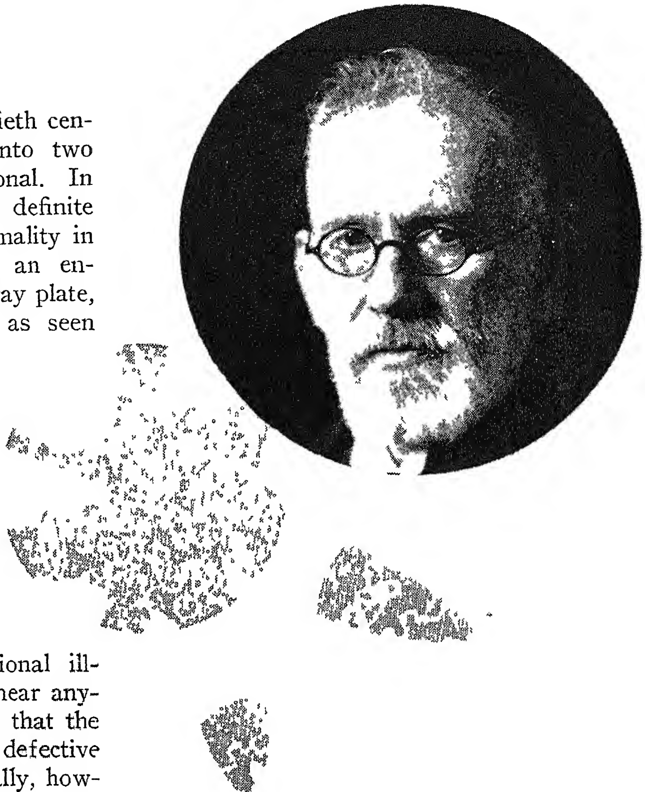
All the advances in the basic sciences — physics, chemistry, biophysics, biochemistry, pharmacology, biology, bacteriology, virology (the study of viruses) and the like — were soon reflected in improved medical practice. The horse-and-buggy doctor of the nineteenth century, who needed no more equipment than he could carry with him, was supplanted by the up-to-date practitioner, armed with all the shiny gadgets of modern medicine. He had at his command wonder drugs and diagnostic devices with which he saved young and old lives that would once have been sacrificed to man's ignorance. The hospital, which people had long feared as a human slaughterhouse, had become a haven when serious illness struck. More and more women went to the hospitals to have their babies.

As the scope of medicine widened, a trend toward "specialism" set in. The favorite specialty in the first part of the twentieth century was surgery, which went on to triumph after triumph. Surgery "removes the disease from the patient and puts it in a bottle." It is one of the most glamorous branches of medicine, especially in the eyes of the layman. Yet a large part of a surgeon's time at the operating table is taken up with the tedious business of tying knots in sutures in order to stop bleeding from cut blood vessels.

Among the great surgeons of this era were the Mayo brothers (Charles and William), who established a renowned medical center and clinic in the little prairie town of Rochester, Minnesota; Harvey Cushing, the great nerve surgeon at Harvard and Yale medical schools; Frank Lahey, of Boston; John B. Murphy, who invented the Murphy button used in abdominal operations; Lorenz Boehler, the Viennese bonesetter who revolutionized the treatment of fractures; Berkeley George Andrew Moynihan (first Baron Moynihan of Leeds), an English surgeon, who perfected many daring abdominal operations. Thanks to the efforts of men like these, every part of the human body could now be operated on.

Many new diagnostic devices in medicine were introduced in the twentieth century. Among them were the X-ray machine, which makes it possible to see inside the human body; the electrocardiograph, which diagnoses irregularities in heart action; the electroencephalograph, which records "brain waves"; the basal-metabolism machine, which tells how fast your body is burning up its food and fat. The use of devices like these has come to be an essential part of medical care. As a result, the cost of such care has gone up greatly. Of course these additional expenditures have saved lives.

In the first part of the twentieth century, doctors divided illnesses into two major classes: organic and functional. In organic illnesses, there was some definite tangible, visible or audible abnormality in the sick person — for example, an enlarged heart, as shown on the X-ray plate, or an infecting microorganism, as seen under a microscope. In functional illnesses, doctors could not see or hear anything wrong, but they could tell that the patient was ill because of the defective functioning of the body. Gradually, however, it became apparent that many diseases and common illnesses — of which stomach ulcers are typical — are neither altogether functional nor altogether organic. They are caused by disturbances of both the mind and body; in other words they are psychosomatic (mind and body) diseases. The work of Sigmund Freud (see page 3483) and his followers in the field of psychiatry (treatment of diseases of the mind) was largely responsible for this new concept. As time went on, therefore, psychiatrists occupied an increasingly important position in the medical field.



Paul Ehrlich, eminent German bacteriologist, made noteworthy contributions to medicine.
Brown Bros

One of the most significant advances in twentieth-century medicine was in the field of chemotherapy, or treatment with chemical drugs. The history of chemistry in medicine goes back at least as far as Paracelsus (see The Renaissance, Volume 2), the erratic, loud-mouthed Swiss physician of the sixteenth century, half doctor, half alchemist, who introduced metals, such as mercury, in the treatment of disease. Modern chemotherapy — even to the coining of the name — begins with the German bacteriologist Paul Ehrlich (1854–1915), a great name in medical history.

Ehrlich was born at Strehlen, in Silesia; he attended a secondary school in Breslau (Wroclaw), and he studied at the universities of Breslau, Strasbourg, Freiburg and Leipzig, receiving the degree of Doctor of Medicine in 1878. He then began to study the relationship between chemistry and medicine. He first worked with aniline dyes, because their effects were visible when they were injected in animals. His life's work was based on the dyes and their derivatives.

When he stained the tubercle bacillus, first isolated by Koch, he found that certain dyes possessed a peculiar attraction for this bacillus. This discovery strengthened his belief that definite chemical substances have a special affinity for the organisms that cause disease. He now determined to develop a drug that would seek out and destroy any and all dangerous germs that might be in a patient's body without harming bodily tissues. This wonder drug was to be known as *magna sterilisans* — Latin for "the great sterilizer."

Ehrlich never discovered the great sterilizer, but he did find one "magic bullet" — a single drug that would kill one particular type of disease germ, the spirochete that causes syphilis. He began the search for it in 1902, assisted by the Japanese doctor Kiyoshi Shiga. One chemical compound after another was prepared and hopefully tried out on rats, mice and guinea pigs. At last, on the 606th attempt, Ehrlich's search was successful — he had discovered a compound that would kill the dreaded spirochete. This compound was a complicated form of arsenic; it was called Salvarsan, or "606" (because it had been discovered in the 606th experiment). Later, Ehrlich proved that Salvarsan could be used safely in the treatment of syphilis in human beings. His discovery opened a new era in the treatment of disease. As time went on, more and more "magic bullets" were developed, and more and more diseases came under frontal attack.

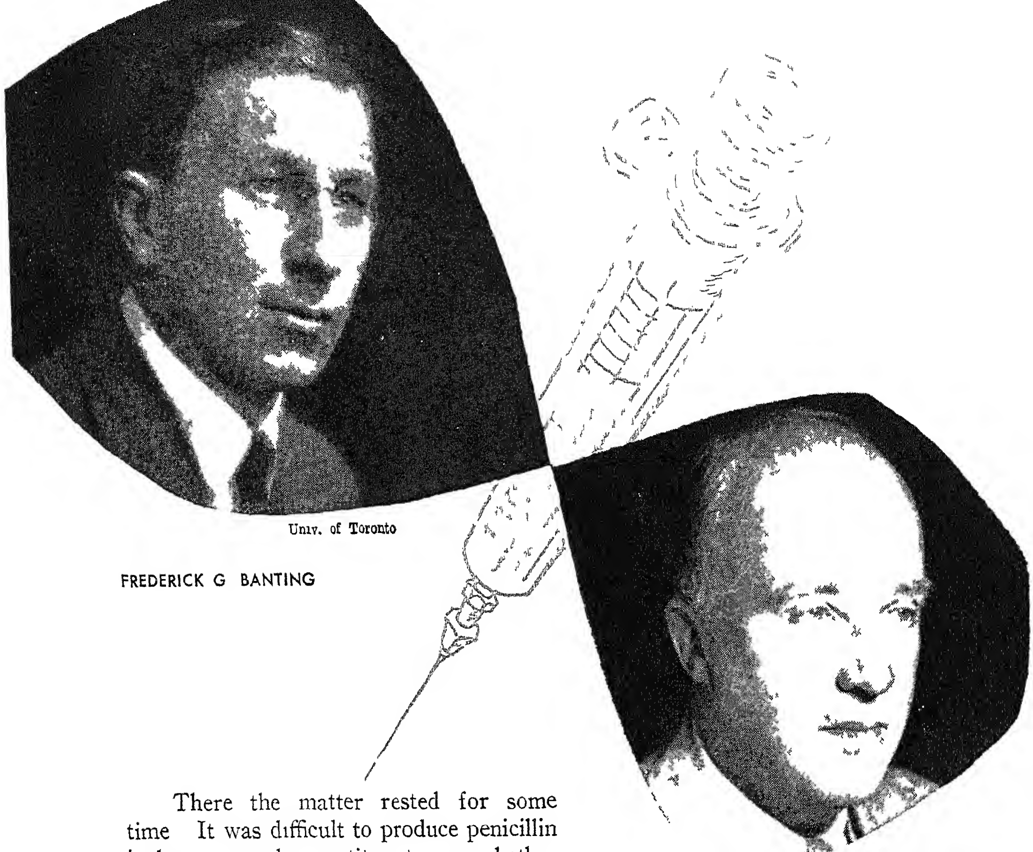
Ehrlich made many other notable contributions to medicine. Among other things, he discovered a method of testing the strength of antidiphtheria serum; he carried out much research on cancer, developing the theory that "the growth of cancer depends on food stuffs." He was also a great teacher. Appointed assistant in the university clinic at Berlin in 1885, he became tutor in 1889 and professor in 1890. His teaching was most informal; he would discuss medical theories with his students in taverns, drinking beer and smoking innumerable cigars. Yet he succeeded in inspiring his students with an eternal zest for scientific research.

Almost every university and learned society in the civilized world paid tribute to Ehrlich's work. The number of decorations conferred on him by crowned heads was so great that he once confessed he could not remember them all. The supreme recognition came in 1908, when the Nobel Prize in medicine was divided between him and the Russian bacteriologist and zoologist Elie Metchnikoff.

Many improved arsenical drugs were soon developed, especially by German chemists. New painkilling drugs, such as Veronal and other barbiturates, were also prepared. For a time, however, there were no spectacular new discoveries in chemotherapy. Medical interest gradually turned to other kinds of remedies — biologicals like antipneumonia serums and hormones like insulin.

A new era in chemotherapy was opened in 1935. In that year the German chemist Gerhard Domagk (born in 1888) announced that he had found a drug, prontosil, that would protect mice against the deadly streptococcus (the so-called strep germ). Prontosil was the forerunner of the now famous sulfa drugs. Actually, it had originally been synthesized in 1908 by another German chemist for use as a red dye. Because of one inconclusive experiment, its healing properties had remained unknown for a quarter of a century. French, English and American investigators quickly seized on Domagk's report and proceeded to develop a whole line of sulfa drugs — such as sulfanilamide and sulfadiazine. These proved effective in the treatment of a whole host of infections — especially pneumonia.

Something even better than the sulfas was in the offing — penicillin, the first of the antibiotic drugs. (An antibiotic is a bacteria-killing substance produced by a living organism.) The discovery of penicillin was one of those numerous lucky accidents of science that sometimes happen to men who are trained to know what they are doing and seeing. This accident happened in the year 1929 in St. Mary's Hospital, in London, England. Professor Alexander Fleming (born in 1881), a bacteriologist, noticed one day that one of the small glass plates in which he was growing bacteria on a culture medium was contaminated with the mold called *Penicillium notatum*. The spot that it covered was completely free from bacteria; hence he suspected that something in the mold was deadly to germs. From *Penicillium notatum* he prepared a broth that he called penicillin. He made the cautious statement that penicillin "might prove to be an effective antiseptic agent . . . against penicillin-sensitive microbes."



Univ. of Toronto

FREDERICK G BANTING

CHARLES H. BEST

There the matter rested for some time It was difficult to produce penicillin in large enough quantities to see whether it would be an effective germ killer. In 1936, however, Professor H. W. Florey and a group of investigators at Oxford began to study the germ-killing properties of penicillin in a systematic way. They were on the right track when their experiments were interrupted by the outbreak of World War II.

Florey came to the United States to seek help in producing the wonder drug in quantity. America's drug industry immediately went to work on the problem; it was assisted by the United States Department of Agriculture, whose experts had been investigating the yeast molds needed to make beer. The problem of quantity production of penicillin was brilliantly solved. On December 7, 1941 — Pearl Harbor day — there was not enough penicillin in the United States to treat a single patient. Before World War II came to an end in 1945, billions upon billions of units had been produced and thousands of lives had been saved.

Other valuable antibiotic drugs were added to the stores of useful medicines after World War II. They included streptomycin, developed by Selman Waksman of Rutgers University — a drug that has brought new hope to tuberculosis victims; tyrothricin, developed by René-Jules Dubos of the Rockefeller Institute, who had long worked with soil bacteria; aureomycin, which receives its name from its lovely gold color; terramycin, and a steadily growing list of others. In fact, a dictionary has been published to list the many antibiotics that have already been developed.

In the twentieth century, new attacks have been made on the deficiency diseases, of which diabetes and pernicious anemia are typical. The discovery of insulin for the treatment of diabetes was made in 1922 by two Canadian scientists — Frederick Grant Banting (1891–1941) and Charles Herbert Best (born in 1899)

Banting was a lecturer at the University of Toronto Medical School at the time; Best was a student in the Medical School. The story of their discovery has been summarized in an inscription on a bronze plaque in the small laboratory where they did their work. It reads:

"On the 30th of October, 1920, Frederick Grant Banting originated the hypothesis that the failure heretofore to isolate the internal secretion of the pancreas [a gland near the stomach] has been due to its destruction by the ferments liberated during the process of extraction. He devised an experimental method by which this destruction could be avoided and the internal secretion [now known as insulin] obtained. In May 1921, Banting and Charles Herbert Best, both graduates of the University of Toronto, conducted in this room the experiments which culminated in the isolation of insulin."

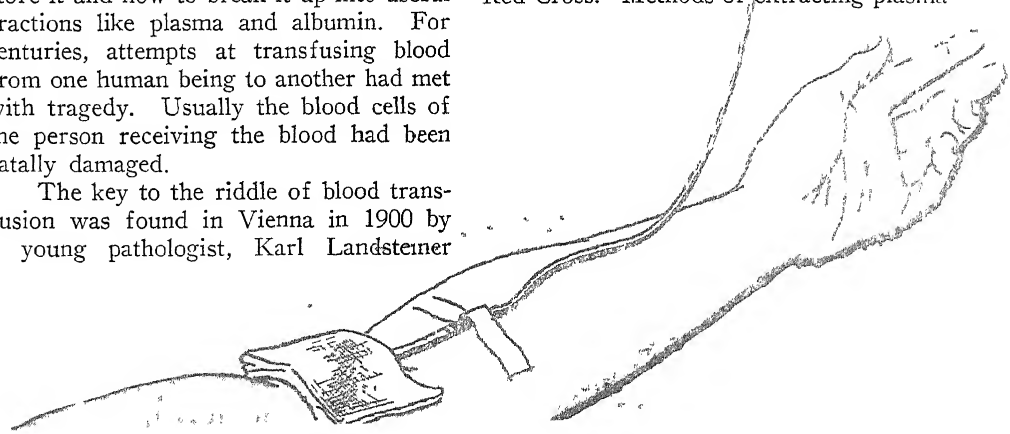
The insulin used in the treatment of diabetes is an animal product. It is made from the pancreases of slaughtered animals. The slaughterhouse has yielded many other medical products — especially hormones and liver extract. The usefulness of whole liver and, later, of liver extract in the treatment of pernicious anemia was first demonstrated, about 1926, by three American investigators, who were awarded a Nobel Prize in medicine for their achievement. These men, all connected with the Harvard Medical School, were George R. Minot, William P. Murphy and George H. Whipple.

In the twentieth century, medical men learned how to transfuse blood, how to store it and how to break it up into useful fractions like plasma and albumin. For centuries, attempts at transfusing blood from one human being to another had met with tragedy. Usually the blood cells of the person receiving the blood had been fatally damaged.

The key to the riddle of blood transfusion was found in Vienna in 1900 by a young pathologist, Karl Landsteiner (1868–1943). He showed that the serum of the blood of one human being is capable of destroying the blood cells of another human being. Armed with this clue, Landsteiner worked out a simple classification of human blood in groups labeled A, B, AB and O. He showed that if the blood of the donor and that of the recipient belong to the same group, blood transfusion is safe and practical. Landsteiner came to the United States in 1919. He solved many other riddles of the blood; thus in 1940 he discovered the so-called Rh factor, which has been responsible for many infant deaths.

The idea of blood storage was worked out by many men, including L. Agote, R. Lewisohn and O. H. Robertson. Then came blood banks, started in Russia by S. S. Yudin but quickly carried over to the United States. The first American blood bank was started at the Cook County Hospital, Chicago, by Dr. Bernard Fantus. The availability of blood, during and after operations, made surgery safer and more daring.

When World War II struck, the armies of the world needed blood in vast quantities for transfusion purposes. An efficient system of blood collecting was set up in the United States by the American Red Cross. Methods of extracting plasma



from whole blood were devised; but whole blood remained the paramount surgical need.

During the war a series of revolutionary experiments on blood were carried on at the Harvard University Biochemistry Laboratories, under the general direction of Dr. Edwin J. Cohn. In a process something like that of cracking crude oil down into fractions of gasoline, kerosene and the like, human blood was broken down into five major fractions. Among them were globulins, which could be used to treat measles, and albumins, which could be dried and used as a substitute for blood in cases of military emergency. The experiments at the Biochemistry Laboratory also yielded fibrin film, which could be used in thin, elastic sheets to line an injured human brain, and fibrin foam, which would stop internal bleeding. The boundaries of surgery and lifesaving were extended by these experiments.

The search for better drugs — "bullets" with more and more chemical magic — continues. We can have some idea of the advances that took place in the first half of the twentieth century by comparing the two following lists of drugs, compiled by a well-known American physician-editor, Dr. Morris Fishbein.

A. *Most Important Drugs in 1910.* — Ether, morphine, digitalis, diphtheria vaccine, smallpox vaccine, iron, quinine, iodine, alcohol and mercury.

B. *Most Important Drugs in 1945.* — The sulfas; penicillin and other antibiotics; whole blood, blood plasma and blood derivatives; quinacrine and other antimalarial drugs; ether and other anesthetics; digitalis; arsphenamines (arsenic derivatives for the treatment of syphilis); immunizing agents, specific sera and vaccines of different kinds; insulin and liver extract; hormones and vitamins.

THE DEVELOPMENT OF THE PUBLIC-HEALTH MOVEMENT

If it is true that man's most precious possession is life, he is truly fortunate today, for he lives longer than ever before. The life span of prehistoric man was 18 years, on the average. By the time of the Roman Empire, life expectancy had increased to about 22 years; during the Middle Ages it reached 35 years. About the middle of the nineteenth century, the average length of life in England was a little less than 41 years. In the United States life expectancy at birth was 47.3 years in 1900; by 1950 it had reached 67.6 and it was pressing toward the Biblical promise of "three score and ten."

One of the most important factors, in modern times, in adding to the years of man has been the public-health movement. It represents the use of community activities, services and resources to improve the health of the public at large. The public-health movement — based on scientific medicine — is a product of the last few generations, but its roots go back to antiquity. For many centuries people have tried to learn about the human body, to find the causes of disease and to develop methods for protecting health.

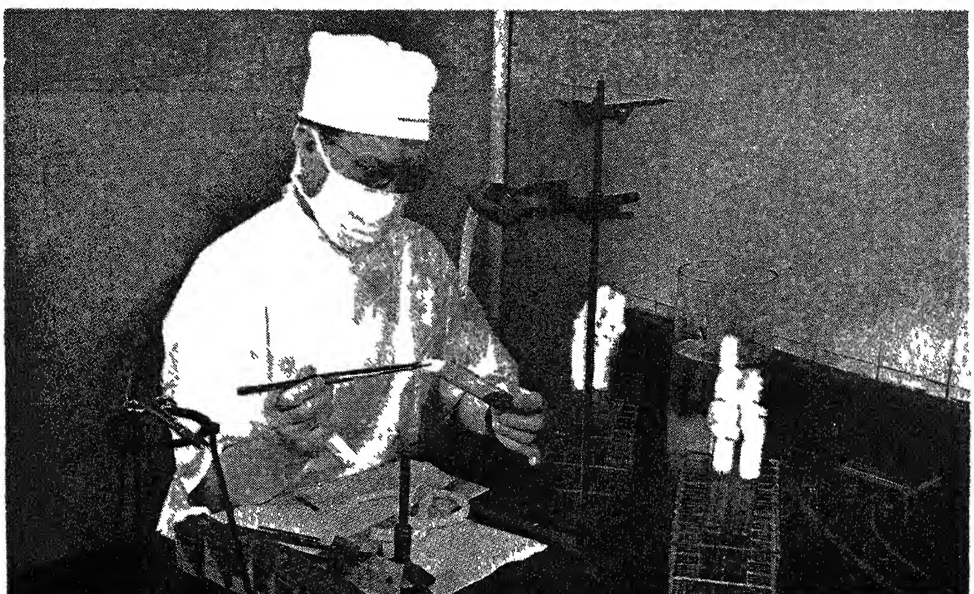
Primitive peoples generally believed that illness was due to evil spirits that entered the body; hence to treat disease, they tried to frighten off these spirits or else to appease them. As early civilizations developed, men learned more about the human body and they devised some useful methods to prevent or treat illness. Thus the ancient Hebrews had some excellent rules for diet and for the control of infectious diseases; the Greeks had comparatively high standards of personal hygiene; in the golden age of the Roman Empire, the Romans paid much attention to sanitation. The Middle Ages was a period of backsliding in the matter of public health. There was, however, one encouraging development: that is, the partial control of certain infectious diseases by isolation. The introduction of quarantine prevented the spread of bubonic plague; following Biblical precedent, leprosy was held in check by compelling lepers to avoid contact with other people. This was the im-

portant public health legacy of the Middle Ages to the Western world.

After the Middle Ages, little progress was made until the nineteenth century. In general the cities of the sixteenth, seventeenth and eighteenth centuries were extremely filthy and polluted, by modern standards, and the small towns and rural areas were not much better. Diseases like smallpox and typhoid fever were rampant, and they attacked every class of society. The situation became even worse with the coming of the Industrial Revolution, for the rise of factories brought thousands of people to the cities and led to fearful overcrowding. Conditions became so bad, indeed, that there was a violent public reaction; men demanded a change. The new interest in human welfare led to reforms in sanitary conditions in factories and prisons; it brought about the development of pure water supplies and better sewage systems.

Sanitary reform was rapid in the first half of the nineteenth century in England, particularly after the establishment of the Poor Law Commission in 1833. Edwin Chadwick, the first secretary of the commission, pointed out that sickness and ill health menaced the community at large; he insisted that the prevention of disease was one of the principal duties of the state As a result of his efforts, a General Board of Health was established in 1848.

The public-health movement in the Western Hemisphere received great impetus in the year 1850, when the Report of the Massachusetts Sanitary Commission was published. This report — the work of Lemuel Shattuck, a Boston stationer — called for the establishment of state and local health departments, the collection and analysis of vital statistics, the sanitation of towns and buildings, the special study of tuberculosis, better care for persons afflicted with mental diseases, the erection of modern tenements and public bathing houses, the control of the smoke nuisance, the protection of foods and improved education for doctors and nurses.



U S Food and Drug Admin

A skilled bacteriologist in the employ of the United States Food and Drug Administration tests a number of samples of surgical cotton to see if they are sterile.

Shattuck's ideas — some of them, at least — were gradually accepted. In 1869, Massachusetts established a State Board of Health, the first in the United States.

As time went on, progressive nations and communities the world over became aware of the importance of safeguarding the health of their citizens But, though the public-health movement made definite progress, until the 1880's the true nature of infectious diseases was not known. Louis Pasteur, Robert Koch and other microbe hunters then revealed, as we have already showed, that these diseases are caused by specific germs. Within the short space of some twenty years, the mystery of the pestilences that had afflicted men for thousands of years was solved.

The bacteriological laboratory now became the headquarters of a vigorous campaign against the diseases spread by polluted water, insects and human contact.

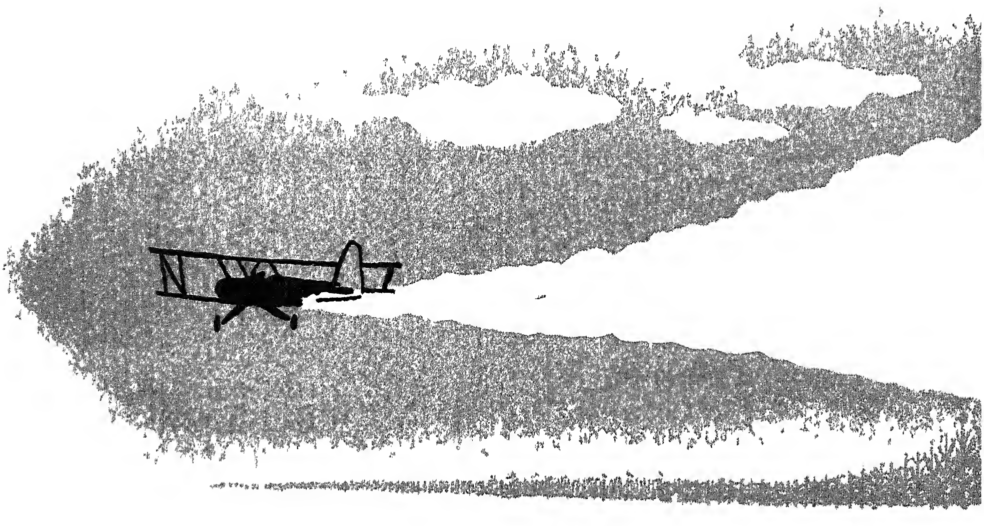
The purification of the water supply had become particularly urgent with the spectacular growth of cities. They had to have large supplies of water for drinking, cooking, bathing and other domestic uses, as well as for industrial purposes. Many of these cities took their water from nearby rivers, which were often heavily polluted with sewage containing dangerous bacteria. The result was a series of widespread epidemics of intestinal diseases.

Sanitary engineers and bacteriologists worked out methods of protecting public water supplies against pollution. Water was stored long enough for most disease germs to die and for suspended matter to settle out; it was aerated — that is, mixed with oxygen; it was often filtered. Finally, in many cities, it was disinfected Originally this was done by adding a small amount of hypochlorite of lime; later liquid chlorine was employed. Since 1951, in many American communities, small amounts of a fluorine compound are added to the water supply to protect children's teeth against decay.

The sanitary protection of water supplies was made easier and more effective by the introduction of better methods for the safe disposal of sewage. Sanitary engineers improved the design of privies, chemical closets and septic tanks. They also developed adequate systems of sewage disposal for towns and cities. We have discussed these systems in the article The Disposal of Wastes in Volume 5.

The purification of public water supplies led to the almost complete disappearance of epidemics of water-borne diseases in most civilized countries. The campaign against insect-borne diseases also yielded spectacular results.

Toward the end of the nineteenth century and in the first years of the twentieth, Kitazato, Yersin, Theobald Smith, Ross, Grassi, Reed and others had demonstrated

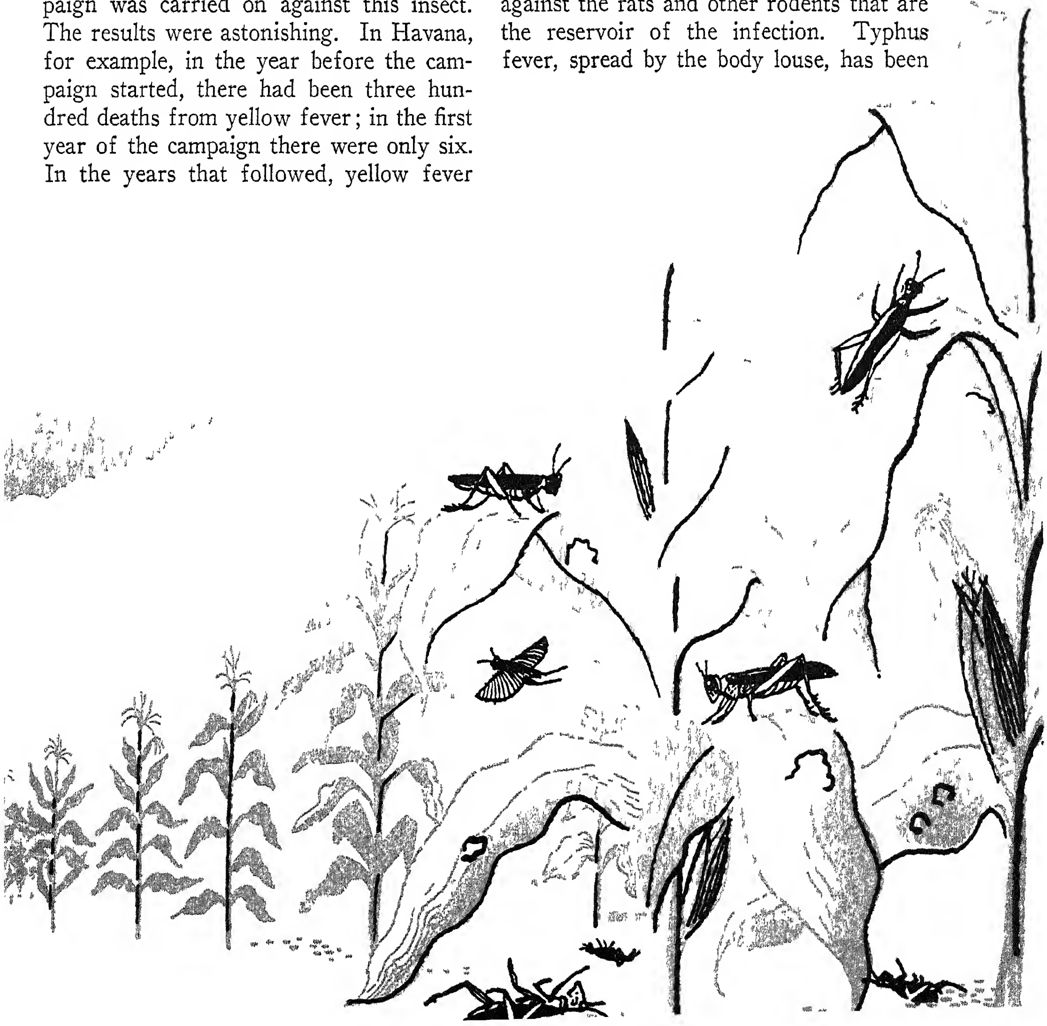


that insects are responsible for the spread of diseases like bubonic plague, Texas fever, malaria and yellow fever. (See Science and Progress VII, Volume 7.) This discovery made it possible to launch a frontal campaign against the insects that cause disease.

Yellow fever, brought over by slavers from the African continent, had long been a scourge in the Western Hemisphere. It had become established in Havana and other seaports of the Caribbean region; by 1793 it had advanced as far north as Philadelphia, where it had killed about one-tenth of the city population. After it had been revealed that the disease was carried by certain species of mosquitoes — especially *Aedes aegypti* — a vigorous campaign was carried on against this insect. The results were astonishing. In Havana, for example, in the year before the campaign started, there had been three hundred deaths from yellow fever; in the first year of the campaign there were only six. In the years that followed, yellow fever was brought under control in one country after another.

Malaria was also checked by cleaning up the places where mosquitoes breed. Since this is not always possible, control of malaria has also depended on the use of quinine and the development of other medicines (such as totaquine, Plasmochin and Atabrine) to treat persons who become infected or to make other persons temporarily immune against infection.

Scientists learned how to keep in check other diseases spread by insects. Bubonic plague, a disease of rats and other rodents, is normally spread from animal to animal and from animal to man by the bite of the flea. The disease has been checked nearly everywhere by a campaign against the rats and other rodents that are the reservoir of the infection. Typhus fever, spread by the body louse, has been



National Film Board

Voluntary health agencies, like the American and Canadian Cancer Societies, play an important part in the war against disease. Above is a cancer information center — the Little Red Door — operated by the Canadian Cancer Society.

controlled by disinfecting the persons and clothing of those infested with lice. In time of war, when the usual practices of cleanliness break down, typhus fever reappears. This happened in World War I and again, to a much lesser extent, in World War II.

Special precautions had to be taken against insect-borne diseases during World War II because so many soldiers had to be sent to tropical countries. The established methods of controlling these diseases were carefully applied. In addition, scientists developed new vaccines against yellow fever and typhus fever and new drugs against malaria They also prepared chemicals to repel or to kill insects The best known of these insect killers — DDT — was dusted from airplanes over wide areas to destroy insect carriers of diseases before troops entered the areas. Solutions of DDT were also sprayed on the walls of homes and hospitals housing patients suffering from insect-borne infections. This really broke the "chain of infection."

Airplane transportation has created new problems and hazards. An airplane can carry an infected mosquito as well as a human passenger from one country to another thousands of miles away in a few hours. New methods of inspection and measures of control have been devised to meet this peril. Among other things, people going to and coming from infected places are vaccinated; airplanes, hand baggage and freight are chemically treated.

All in all, man is winning his battle against insect-borne diseases. The fight against diseases spread from one person to another by contact has not been so successful. To control them, health authorities have urged the public to avoid contact with infected persons or with discharges from their bodies. But such precautions have not always proved effective. For one thing, some of these diseases can be spread in more ways than one; thus, diphtheria may be communicated through food as well as by direct contact. Again, it is difficult in actual practice to avoid all contact with persons having infectious diseases Furthermore, an individual may spread the disease germs before he or anyone else is aware that he has the disease; he may have the disease in such a mild form that it is never recognized; he may be a "healthy carrier" — that is, he may carry and spread germs without being sick himself.

It is almost impossible, therefore, to avoid all contact with persons harboring the germs or viruses of diseases like typhoid fever or poliomyelitis (infantile paralysis). Fortunately, people can be protected against certain diseases even if they are exposed to them; they can be rendered immune by vaccines or other preparations. Vaccination affords certain protection (for a number of years) against

smallpox; the use of toxin-antitoxin or toxoid protects against diphtheria; many other immunizing agents have been developed. Improvements in diagnosis and treatment have also helped greatly.

Formerly, the public-health movement was mainly concerned with the sanitation of the environment and with the control of communicable diseases. In recent years, it has developed a new program of education; it has sought to teach people how to lead healthy lives. Public-health agencies have had to devise ways to bring health information to the public. Health departments now include educational experts as well as sanitary engineers; health literature is considered almost as important as laboratory tests.

Education has played a large part in the continuing fight against tuberculosis of the lungs (consumption). Millions of families are made aware of this fight yearly through the Christmas seals sold by the National Tuberculosis Association. Education has also proved helpful in lowering the infant mortality rate, in combating the diseases that come mainly in middle life and old age and in preserving the mental health of the public.

The activities of public-health agencies formerly centered about community-wide services rather than on services for particular persons. Individual care was furnished by such agencies only for those who were wards of the community because of poverty, crime or mental breakdowns. In recent years, however, the agencies have had to accept more responsibility for the care of individual patients. The first large-scale treatment programs were for persons suffering from tuberculosis or mental disease. In these cases, society decided to furnish care to patients at public expense because they were a source of danger to the community and because few families could meet the expenses of long-continued care in special institutions. Public agencies then began to provide services for many other diseases. They operated special hospitals; they set up clinics for immunizations and for the diagnosis and treatment of certain diseases. They gave advice and care to pregnant women, infants, crippled children and school children with diseases or defects Many of these services have been greatly extended in recent years. Others have been reduced as the need for them has become less urgent

School health services have also become increasingly important. The educational and public-health authorities are in charge of many of these services. Thus they seek to provide proper sanitation in school buildings, as well as suitable heating, lighting, ventilation, seating arrangements and so on. They instruct pupils in personal hygiene and in community health. They look after the physical development of children through exercises and recreation under supervision; sometimes they provide nutritious lunches free or at reduced cost. School physicians and nurses watch over the health of the children. Some health departments have established clinics where poor school children can obtain needed medical, dental or hospital care free or for a nominal fee.

The organization of public-health work is much the same in different countries, though details vary considerably. As a general rule, each country has a national health agency that has over-all responsibility. In the United States, for example, there is the United States Public Health Service, a division of the Federal Security Agency; in Canada, the Department of Health and Welfare. There are also local health departments that provide or oversee most of the services needed by the community. In the United States and Canada, there are also state (in Canada, provincial) health departments.

All these agencies rely upon vital records, or vital statistics, which supply data about population, births, deaths, communicable diseases, marriages and divorces. As we learned in a previous chapter, statistics of this kind go back to the Natural and Political Observations on Bills of Mortality, published in London in the year 1662 by Captain John Graunt and Sir William Petty. Many improvements in methods of keeping vital statistics have been made from that time to this.

In addition to the official public-health departments, there are a great many voluntary or nonofficial health agencies. In the United States, these include the American Red Cross, the National Tuberculosis Association, the American Cancer Society, the American Heart Association, the National Safety Council, the American Diabetes Association, the National Foundation for Infantile Paralysis and a good many others. Altogether there are about twenty thousand local chapters of voluntary health organizations now in operation in the United States and they use the services of several hundred thousand people.

There are also a number of voluntary public-health agencies in Canada. One of the most important of these is the Health League, which is particularly interested in health education and in supporting the official health departments. Other voluntary Canadian agencies include the Canadian Red Cross Society, the Victorian Order of Nurses for Canada and the Order of St. John.

Thus far we have been considering only the health agencies that function within national boundaries. But, after all, diseases may be carried from country to country, from continent to continent. No country can achieve permanent protection unless such diseases are held in check everywhere. To bring this about, it is necessary to go beyond national boundaries.

International efforts to control disease started a number of years ago. A tentative step in this direction was the organization of the International Red Cross in the nineteenth century. In 1907, the International Office of Public Hygiene was established, with its headquarters in Paris. It collected information from about forty countries, especially concerning diseases such as Asiatic cholera, plague and yellow fever, and it published that information regularly. International agreements were worked out on quarantine and other methods of controlling communicable diseases.

Following World War I, the League of Nations established a Health Section, and in 1923 this was combined with the older International Office. Until the outbreak of World War II, the Health Section was the main international health organization. Though the United States was not a member of the League, American health authorties co-operated fully with the Health Section. It ceased to operate when the League of Nations was disbanded in 1946.

In the Western Hemisphere, similar work has been done by the Pan-American Sanitary Bureau. Many international public-health services have also been made possible by the International Health Board of the Rockefeller Foundaton and by other private organizations.

In 1946 the United Nations drew up plans for a new agency for the improvement of public health the world over. This World Health Organization (WHO), as it was called, began to operate in 1948 The objective of WHO, as stated in its constitution, is "the attainment by all peoples of the highest possible level of health." The agency aims to promote the improvement of nutrition, housing, sanitation, recreation, economic conditions, maternal and child health; to promote co-operation among scientists and to encourage and conduct research; to promote improved standards of professional teaching and training; to develop international standards for food and biological products and "generally to take all necessary action to attain the objectives of the Organization."

WHO has been greatly hampered by the international tension existing at the present time; yet it has already done much. It has launched a campaign for the elimination of the *Aedes aegypti* mosquito in the Americas, assisted Peru and Bolivia in typhus-control programs, co-operated in setting up an antituberculosis center in Istanbul, Turkey, carried out a rabies-control project in Israel and aided Saudi Arabia in an antismallpox campaign. WHO has shown the world the happy results that can be achieved through the wholehearted cooperation of the countries of the world on a truly international level.

SCIENCE THROUGH THE AGES is continued on page 3433.

TWO BIG OUTER PLANETS

The Plumbing of the Depths of Space to Find
Slow-Moving Uranus and Neptune the Invisible

PROBLEMS OF THE PLANETARY SYSTEM

LEAVING behind us Saturn and his gorgeous retinue of rings and satellites, we must now proceed to the outer confines of the planetary system. Two planets circulating at vast distances from the sun, Uranus and Neptune, remain to be considered, as Pluto has already been discussed. We shall review certain general questions of their origin and history.

Saturn was the last of the planets known to the ancient world; we have precise observations of its position and movements from as far back as the third century before Christ; and as a star of the first magnitude it must have been well known from the earliest times when men began to observe the sky. From that remote period until near the end of the eighteenth century, no new planet was discovered, although Uranus was all the time quite visible to clear eyesight. But, slowly as Saturn moves among the stars, Uranus moves far more slowly, taking over 84 years to complete a single circuit of the sun. There was therefore no possibility that the wanderings of this distant world should be noticed, and its planetary nature discovered, until the science of astronomy was far advanced and had become highly organized. Neptune, which until 1930 was known as the outermost planet, is too faint in the heavens to be visible to the unaided eye, and could never have been discovered except for the union of finely constructed astronomical instruments with the highest powers of mathematical reasoning. Uranus was found by accident, but the existence and position of Neptune were predicted, by exact calculations, before the planet had ever been seen.

Sir William Herschel, the eminent German-English astronomer, never satisfied with the performances of his instruments, made with his own hands one after another of ever-increasing size and power, until he finally had a better telescope than any other then existing. It was on March 13, 1781, that he discovered Uranus, which he took at first to be a comet. He was searching through the constellation of Gemini when he came upon a star which appeared to show a disc, being thus distinguished from fixed stars, which remain mere points of light even under the highest powers of the telescope. He found that this star could just be seen without a telescope, being of the brightness known as the sixth magnitude. Turning a higher power upon it, he noticed that its disc was enlarged in proportion. There was then no question that he had come upon some celestial body other than a fixed star.

Observing it on successive nights, he perceived that it changed its position among the stars. Still, however, it never occurred to him that this might be a planet. The number of the planets had been known from antiquity, and telescopes had been freely used for over a century and a half without the discovery of a new one. It was natural that Herschel should come to the conclusion that his moving star was a comet; and it was under that title that he published his account of its discovery.

The supposed comet was carefully followed at the principal observatories of Europe, and was found to move far otherwise than a comet might be expected to do. Instead of pursuing an extremely eccentric elliptical path, so as to pass comparatively near the sun, and then to plunge into re-

mote distances of space, the new star gradually revealed an apparently circular orbit, situated far outside the orbit of Saturn. As the months went on, this circular orbit became more certain, and Sir William was soon acclaimed as the discoverer of a new planet which he named *Georgium Sidus* ("George Star", after his royal patron George III of England) but which others, for some years, called after its discoverer "Herschel".

The improved namings of the planet which Herschel found

But the name Uranus, which was proposed by the German astronomer Bode soon after its discovery, received at last the sanction of the scientific world, as more in accordance with the method in which the other planets had been named. In ancient mythology Uranus was father of Saturn and grandfather of Jupiter. After the planet's orbit had been fully calculated, it was found that Uranus had been seen many times before, and noted down on star-maps as a fixed star.

The mean distance of Jupiter from the sun is 483,000,000 miles, that of Saturn 886,000,000 miles; and that of Uranus nearly 1,800,000,000 miles, or twice the distance of Saturn. The orbit of Uranus is fairly eccentric, so that the planet is 166,000,000 miles nearer to the sun at perihelion than it is at aphelion. It was last at perihelion — that is to say, the point in its orbit which is nearest to the sun — in 1883, and will return to the same position in 1967. The orbit is inclined to the plane of the ecliptic by less than one degree. Uranus moves in its orbit at a speed of about $4\frac{1}{3}$ miles in a second, and performs a complete circuit of the sun in 84 years and 8 days. The earth passes between Uranus and the sun once in every 369 days and 9 hours.

Doubts that come with extreme distances in space

The great distance of this planet from our earth makes measurements of it very doubtful, but its disc has a diameter of about four seconds, which would give it a real diameter of about 32,000 miles, or four times the earth's diameter. Its volume is about sixty-four times that of the earth; but as the density of Uranus is exceedingly low, being only slightly more than that of water, its mass is only about fifteen times that of the earth.

The remarkable lightness of the materials of which Uranus is composed shows that this planet, like Jupiter and Saturn, is mainly in the vaporous condition. Its polar flattening, due to the centrifugal force developed by its rotation on its own axis, is such that the equatorial diameter exceeds the polar diameter by about one in twelve, a degree of compression which makes the globe obviously elliptical to the eye. The speed of its rotation has not been observed with any certainty, but its period is probably about ten hours. Uranus is tilted over in an excessive degree, though quite how much is still open to question.

Being more than nineteen times the distance of our earth from the sun, Uranus receives only one-368th part of the light and heat which we receive. It is, however, a good reflector, owing to the fact that its visible surface consists of cloud. It has a very characteristic sea-green color, due to the absorption of the red and orange components of sunlight by its enormously deep atmosphere, which extends far outside the visible surface of cloud.

The moons of Uranus and the peculiarity of their orbits

Uranus has five moons, which have been given the poetic names of Ariel, Umbriel, Titania, Oberon and Miranda; astronomers suspect that there may also be a sixth moon. These satellites are very faint because they are so small. Their orbits lie very close together. The remarkable peculiarity of the satellites of Uranus is that the plane of their orbits, instead of lying more or less in the plane of the planet's orbit, is almost vertical to that plane. The plane in which these satellites revolve is consequently seen from the earth sometimes edgewise and sometimes in full face. The plane of the orbits is tilted up very nearly 98° so that it is a little past the vertical, and consequently the moons revolve in the retrograde direction.

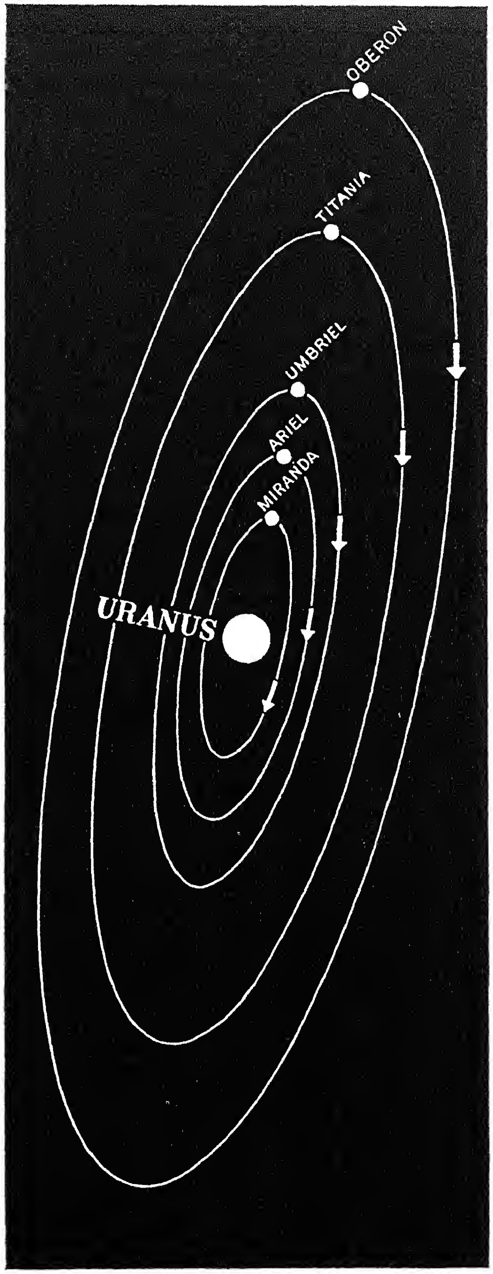
The discovery of the planet Neptune in 1846 by purely mathematical reasoning, based on the movements of Uranus, was one of the most astonishing feats in the history of astronomy. It was accomplished by comparing the predicted positions of Uranus at various dates with the positions it actually occupied at those dates.

A part of the laborious routine of astronomy is the calculation beforehand of the various positions that the several planets will occupy in succeeding months and years. Tables of these predicted planetary positions are published. Observers who are making a nightly study of the skies become aware very soon indeed of any discrepancy between a predicted position in one of these celestial timetables and the actual position of a given planet at that time. So exact are the methods of calculation and so regular are the planetary movements that a discrepancy of this kind at once suggests some unknown cause that has not been allowed for in the calculation.

A French astronomer's momentous discovery

The French astronomer Alexis Bouvard was at work in 1820 upon the timetables of Jupiter, Saturn and Uranus. He found that the first two of these planets kept to their predicted positions but that Uranus departed from it by a very minute and yet measurable distance. He gave it as his opinion that the planet that then formed the limit of the solar system was disturbed in its orbit by the attraction of another planet that was still more remote. Year after year the discrepancy increased. From a distance of 20 seconds of arc in the year 1830, it became 90 seconds of arc in 1840 and 128 seconds of arc in 1846.

The entire astronomical world was intrigued by this fascinating problem. The French astronomer Urbain Jean Joseph Leverrier and the English astronomer John Couch Adams attacked the problem independently and solved it simultaneously. In October 1845, Adams approached Sir George Airy, Astronomer Royal at Greenwich Observatory, with his calculations of the position of the new planet. It was not, however, until July of the following year that Professor James Challis, of Cambridge, began the search for it at Airy's request. In June 1946, Leverrier's calculations were published. In September, Sir



Uranus and its satellites. All five satellites revolve in the opposite direction from that in which most members of the solar system revolve.

John Herschel, addressing the British Association, announced the prospect that another planet was on the eve of discovery. "We see it," he said, "as Columbus saw America from the shores of Spain. Its movements have been felt trembling along the far-reaching line of our analysis, with a certainty hardly inferior to occular demonstration."

In the same month Leverrier wrote to Dr. Johann Gottfried Galle, of the Berlin Observatory, asking him to search for the new planet; and on the night of September 23 on which date he received the letter, Neptune was found within one degree of the position Leverrier had predicted.

A planet that was seen, yet not discovered as a planet

On October 3, Sir John Herschel published a statement of the calculations which Adams had made, and claimed for him an equal share in the honor of the discovery. There followed a somewhat unworthy controversy between the partisans of the two astronomers, but it is now generally admitted that they were equally deserving. As in the case of Uranus, it has since been ascertained that Neptune had been seen several times, and its position noted, before the discovery that it was a planet.

Neptune pursues a vast orbit, having a mean distance from the sun of 2,800,000,000 miles. This orbit, which is very slightly eccentric, is inclined to the plane of the ecliptic by less than two degrees. The planet moves at a speed of about $3\frac{1}{3}$ miles a second, and takes 165 years to complete its circuit of the sun. Its apparent diameter is about $2\frac{1}{2}$ seconds, and its real diameter about 33,000 miles. Its volume is about 78 times that of the earth, but its mass exceeds the mass of the earth by only about 17 times. That is to say, like the other major planets, it has very low density, and hence the greater part of its mass must be in the vaporous state. Like Uranus, which it resembles in several respects, Neptune shows a blue-green disc, invisible to the unaided eye, but plain enough through an ordinary field-glass. It is ranked according to its brilliancy as a star of the ninth magnitude.

Why the earth cannot be seen from Neptune though we see Neptune

As a reflector, it is inferior to Jupiter, Saturn and probably also to Uranus Owing to its great remoteness from the center of our system, the sun would appear to Neptune no larger than Venus appears to us; and this distant planet receives only one-900th part of the light and heat which we receive from the sun. From the surface of Neptune it would be impossible to see any of the planets within the orbit of Jupiter, and Jupiter itself would appear as a morning and evening star in close attendance on the diminished sun.

The planet has a profound atmosphere, extending far outside its visible surface of cloud, and cutting off the red and orange constituents from the sunlight which it reflects. The spectroscope shows that there are elements in the atmosphere of Neptune, as of Uranus, Saturn and Jupiter, which are compounds of hydrogen.

Although Neptune revolves round the sun in the direction in which the other planets proceed, its rotation about its own axis is believed to be retrograde; and the plane of its equator is inclined by about 35° to the plane of its orbit. There are no clear markings on the surface of Neptune. The planet has only one satellite; or perhaps we should rather say that only one has as yet been discovered. This was first seen by Lassell on October 10, 1846, eighteen days after the discovery of Neptune. It is of about the size of our moon; and its revolution round the planet is in the retrograde direction. From a discussion of 1500 observations made between 1864 and 1908, Arthur Newton of the American Nautical Almanac Office has found that the satellite revolves in a plane inclined by 14.7° to the plane of Neptune's equator. Distant by about 223,000 miles from its planet, it makes a complete revolution in somewhat less than 6 days. Though discovered in 1846, Neptune has not yet been observed through a complete passage of its orbit. Not until the year 2010 will this distant planet have completed its prodigious circle. The solar system has now been extended to include Pluto.

The Twentieth Century (1895-) III

by JUSTUS SCHIFFERES

THE STUDY OF THE HUMAN MIND

THERE is, perhaps, no field of science in which there has been more controversy than in psychology — the study of the mind. The fact is that *scientific* psychology is a very young science, an exceedingly difficult discipline and an area of human knowledge in which there are perilously few facts to work with.

Psychology, the child of physiology and philosophy, was grudgingly accepted as an independent science in the 1890's. Three men were primarily responsible for this development: the German physiologist Von Helmholtz, whose work in other connections we have already discussed; the American philosopher William James, with whose work we shall deal more fully in this chapter; and the Austrian physician Sigmund Freud, whose life and contributions to the understanding of the subconscious mind will be discussed later.

Psychology today has many different branches. *Physiological psychology* concerns the structure and function of the sense organs and the physical bases of behavior. *Comparative psychology* deals with the behavior of animals, such as the dog, the rat and the ape. *Developmental psychology* attempts to trace the progress and changes in human behavior and mental attitudes in individuals. *Child psychology* studies the problem of bringing up children so that they may fully realize their potentialities. *Differential psychology* compares the behavior of the individual with that of the group in which he lives or else analyzes the behavior of different groups. *Applied psychology* puts scientific psychology to work in such fields as advertising, selling and law. *Abnormal psychology* deals with irregular mental phenomena, including hallucinations, mental diseases and feeble-mindedness.

Abnormal psychology is closely related to the branch of medicine called psychiatry, which deals with mental disorders. There is, however, a marked distinction between psychology and psychiatry. Psychology is a body of knowledge that has resulted from studying the mental reactions of men and animals. Psychiatry is a branch of medicine whose chief aim is the treatment of persons suffering from mental — or, as we now say — emotional ills. A psychiatrist is first of all a doctor of medicine; he is a medical specialist. We discuss psychiatry in the following chapter.

The study of the human mind goes back to antiquity. The story goes that when the Athenian philosopher Socrates was a young man, he heard that a noted philosopher had just written a treatise bearing the title WHAT IS MIND? Socrates hurried down to the market place, obtained a copy of the treatise and eagerly read it. When, later, a friend asked him what was contained in the book, he answered ruefully, "Wind!" Perhaps Socrates was a little hard on the author of WHAT IS MIND? Yet the fact remains that, until the late nineteenth century, most of the discussions of mind — and they were many — were based on pure speculation.

That is true, for example, of Aristotle's treatise ON THE SOUL, the foremost work on psychology in antiquity. Aristotle defined mind, or soul (*psyche,* in Greek), as synonymous with the principle, or essence, of life. It is found, he said, in

every part of the body; but its center is the heart. He divided the processes of knowing, or conscious life, into three stages: (1) sensation, (2) imagination and (3) rational thought. All knowledge, he maintained, is derived from sense perception; the mass of sense perceptions are brought together by imagination, are firmly fixed by memory and are acted upon by reason.

All this is interesting enough, but it is simply one man's opinion. Yet it served as the basis of most psychological systems down to comparatively modern times. These systems, advanced by men like Thomas Hobbes, René Descartes, John Locke, Julien Offroy de La Mettrie, the Abbé Etienne Bonnot de Condillac and David Hume, are discussed in histories of philosophy; they hardly come under the head of scientific inquiry.

It was not until students of psychology began to base their studies upon experimentation and direct clinical observation that psychology began to emerge as a science. These early students of psychology owed much to the researches of physiologists who collected data on the workings of the nervous system. The British anatomist Sir Charles Bell (1774–1842) revealed the distinction between sensory nerves (conveying nerve impulses inward from the sense organs to the brain and other nerve centers) and motor nerves (transmitting signals outward from the central nervous system to the muscles). The French physician François Magendie (1783–1855) demonstrated that the two roots of the spinal nerves are devoted to separate functions. Important experiments on vision, color contrast and the sense of hearing were carried out by the German physiologist Johannes Mueller (1801–58). Ernst Heinrich Weber (1795–1878), a German anatomist, formulated what came to be known as Weber's law: namely, that the human mind and body perceive relative, but not absolute, changes in the intensity of the outer forces that act upon them.

The great German physicist Hermann von Helmholtz, whom we discussed in an earlier chapter, was greatly interested in the phenomena of perception. He measured the rate of transmission of nerve impulses; he showed that nerve signals are not instantaneous but that it takes time for them to go to or from the brain. Von Helmholtz also delved into the mechanism of sight and color vision. His work on the mechanism of hearing and on the qualities of tone led him to publish a treatise THE SENSATIONS OF TONE AS A PHYSIOLOGICAL BASIS FOR A THEORY OF MUSIC (1862).

All these men laid the foundation upon which Wundt and other psychologists of the last half of the nineteenth century were to build. Wilhelm Wundt (1832–1920) has been hailed as the father of experimental psychology. Born at Neckarau, in Baden, he studied medicine at Tuebingen, Heidelberg and Berlin and began to lecture at Heidelberg in 1857. In 1875 he became professor of philosophy at the University of Leipzig.

Wundt's ideas concerning psychological research

Wundt believed that the psychologist should study the bodily bases of behavior, perceiving, thinking and imagining. Research, he thought, should be focused upon a particular problem, not upon a whole field of inquiry. Methods of exact observation should be employed under properly controlled conditions. To make such research possible, he established at the University of Leipzig the first psychological laboratory to be found anywhere in the world. Eager young psychologists-to-be flocked to it from all over the world.

Wundt formulated the theory that is called structuralism. It is based on the assumption that different sensory impressions exist in and by themselves, and that the brain fuses them or otherwise brings them together. Man's total mental life, according to his theory, is a structure, built up from sensory experiences.

Wundt also attempted to apply the methods of experimental psychology to the field of anthropology. In his masterly FOLK PSYCHOLOGY (of which the first part

appeared in 1900), he discussed the development of language, custom and religion from the psychological point of view. He traced their origins to "gestures, vocal sounds, imagery and habit." But his was by no means the final answer.

Many of Wundt's students went forth from his laboratories to spread the doctrine of the new psychology through the Old and New Worlds. Among them was Emil Kraepelin (1856–1926), a German psychiatrist, who established one of the best classifications of mental diseases. One of Wundt's most influential American disciples was G. Stanley Hall (1844–1924). He founded the first psychological laboratory in the United States at the Johns Hopkins University in Baltimore, Maryland, in 1882. Later Hall became the President of Clark University in Worcester, Massachusetts, and made it a great center of psychological study. He was particularly interested in child and adolescent psychology. He wrote a number of important works in those fields, including CONTENTS OF CHILDREN'S MINDS ON ENTERING SCHOOL (1894), YOUTH — ITS EDUCATION, REGIMEN AND HYGIENE (1907) and EDUCATIONAL PROBLEMS (1911).

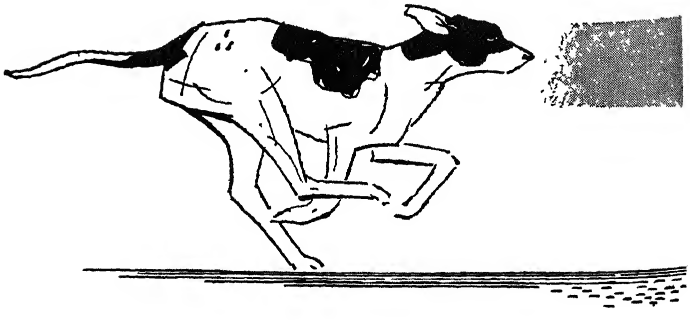
Other distinguished students at Wundt's laboratory were Cattell and Titchener. James McKeen Cattell (1860–1944) taught at the University of Pennsylvania and at Columbia University. He made important studies of reaction time, of mental testing and of the backgrounds of American scientists. He was the editor of SCIENCE and THE SCIENTIFIC MONTHLY, two distinguished journals of science which passed, in 1946, from the ownership of the Cattell family into the hands of the American Association for the Advancement of Science. Late in life, Cattell founded the Psychological Corporation, which aimed to put psychology at the service of industry Edward Bradford Titchener (1867–1927), an Englishman by birth and a naturalized American citizen, brought Wundt's theory of structuralism to the United States and expounded it at Cornell University.

Undoubtedly the greatest name in the early history of American psychology is that of William James (1842–1910), who rivaled Wundt in the range and influence of his work. Born in New York City, educated in Europe and at Harvard, James taught or lectured at many universities, in-

WILLIAM JAMES

cluding Harvard, Stanford, Columbia and Edinburgh, in the course of his brilliant career. He was the brother of Henry James, the novelist. Henry was famous for his subtle delineation of character; William expressed subtle ideas with admirable precision of language. Hence it is said that "Henry James wrote novels like a psychologist; William James wrote psychology like a novelist."

William James's PRINCIPLES OF PSYCHOLOGY, published in 1890, is a landmark in the history of psychology. James was a functionalist — that is, he maintained that psychologists should analyze the functioning of the mind instead of concentrating on ideas, images and feelings. His most original contributions to psychology dealt with instinct, the transfer of training and the analysis of the emotions. With Carl Lange (1834–1900), a Danish physiologist, he set forth in 1884 the so-called James-Lange theory of emotion. According to this theory, "bodily changes follow directly the perception of an exciting fact [e.g., meeting a bear; being insulted by a rival]. Our feeling of the same [bodily] changes as they occur *is* the emotion."



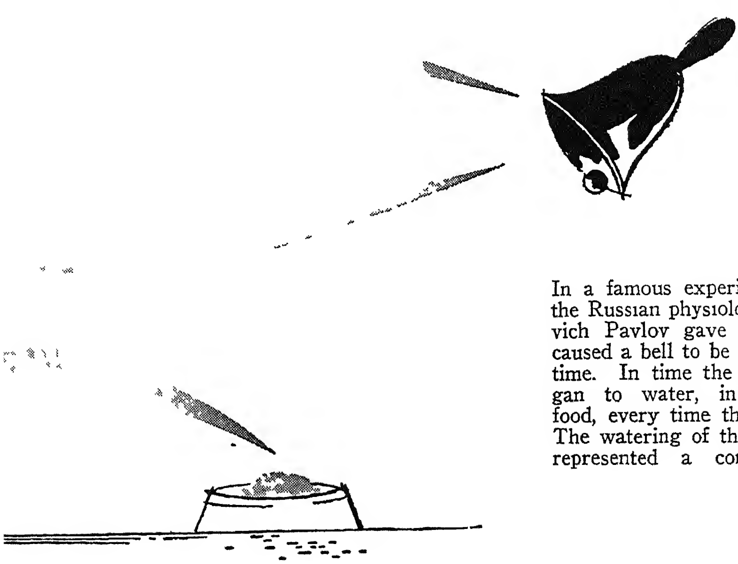
In his later years, James turned to philosophy; in fact, he once referred to psychology as a "nasty little subject" that he was delighted to have put behind him. He delved into such problems as free will and determinism, the nature of God and the immortality of the soul. He held out hopefully for a religion of "healthy-mindedness," and wrote beautifully on THE VARIETIES OF RELIGIOUS EXPERIENCE (1920).

James was the first important American functionalist. Others who taught the doctrines of functionalism were John Dewey (1859–1952) and James Rowland Angell (1869–1949). When these two men were at the Universty of Chicago, in the early 1900's, they stressed the importance of seeking total adjustment to one's environment; only through such adjustment, they maintained, could man fulfill his needs. In later years Dewey became an influential educational psychologist at Teachers College, Columbia University; Angell served for many years as the President of Yale University.

Some of the most important advances in psychology have resulted from the study of animal behavior. However, the experiences of a rat in a maze or a monkey with a stick cannot be used as guides for human behavior. The excessive enthusiasm of some earlier psychologists for interpreting complex human behavior in terms of simple animal experiments at one time gave psychology a bad name and retarded its genuine development.

One of the pioneers in the field of animal psychology was the Canadian-born British biologist George J. Romanes (1848–94), an intimate friend of Charles Darwin and an apostle of his ideas. Romanes believed that fish display emotions of anger, fear and jealousy and that cats and monkeys delight in torture for torture's sake. There is much interesting material in Romanes' many books, but much nonsense also. For one thing, Romanes was guilty of what literary critics call the pathetic fallacy — that is, he read his own feelings into the animals he was describing.

The great Russian physiologist Ivan Petrovich Pavlov (1849–1936) skillfully utilized the experimental method in the study of animal reactions. In the year 1901, he discovered something of tremendous importance to psychology — the conditioned reflex, first analyzed in dogs. The



In a famous experiment with dogs, the Russian physiologist Ivan Petrovich Pavlov gave a dog food and caused a bell to be rung at the same time. In time the dog's mouth began to water, in anticipation of food, every time the bell was rung. The watering of the animal's mouth represented a conditioned reflex.

conditioned reflex (or CR, as psychologists write it) may be briefly explained as follows, on the basis of a famous experiment of Pavlov's. A dog is given food and a bell is rung at the same time. Soon the dog's mouth begins to water in anticipation of food every time the bell is rung. The ringing of the bell is called a stimulus; the watering of the mouth, a reflex action. This reflex action constitutes a conditioned reflex, because it was conditioned, or occasioned, by the ringing of the bell.

Some of the most significant experiments with cats and dogs were done at the Harvard Physiological Laboratory by Walter B. Cannon (1871–1945), who confirmed James's ideas about the relation between emotions and bodily changes. Cannon's experiments threw light on the physical changes that take place in animals when they are under the influence of pain, hunger, fear or rage. Such changes are to be found in man as well as in the higher animals. When a cat, dog or man is threatened, the body reacts by sending "chemical messengers" (hormones) into the blood stream — especially adrenalin, the "emergency hormone," from the adrenal glands. This accounts for the great reservoir of power that certain men often find in the heat of battle; in other words, emotions may make us stronger than usual.

Robert Yerkes studies the mental life of animals

A good deal of important work on animal intelligence was done by the comparative psychologist Robert Yerkes (born in 1876), who taught at the University of Minnesota and at Yale. Yerkes made an intensive study of the mental life of monkeys and apes. He came to the conclusion that the mind of a higher ape such as the chimpanzee is more manlike than monkeylike in the way in which it functions; he conceded, however, that the content of the chimpanzee mind is monkeylike. Yerkes also made some interesting experiments with crustaceans and frogs; he showed that these animals, certainly not noted for their mental prowess, could be trained to make their way out of a maze.

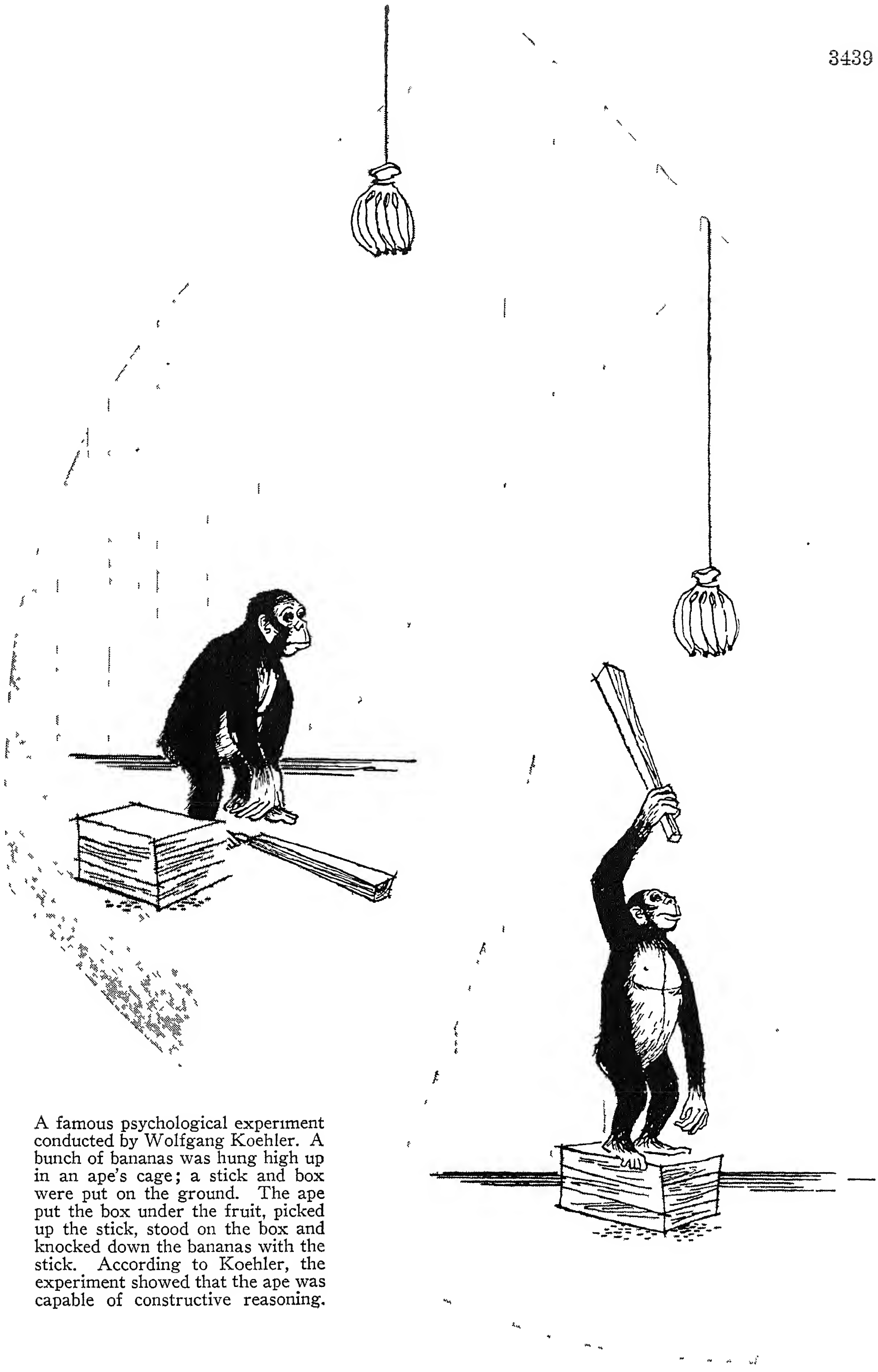
A great stir in psychology was created by the rise of the behaviorist school just before the outbreak of World War I. The founder of this school was John B. Watson (born in 1878), an animal psychologist at the Johns Hopkins University. Leaning heavily on Pavlov's concept of conditioned reflexes, Watson insisted that psychology must not concern itself with the states of mind of a given individual but with his behavior — that is, his responses to definite stimuli. Watson proposed to note the smallest units of stimulus-response relationships (that is, conditioned reflexes); to find out how they could be altered by more favorable conditioning; to see how they operated in larger patterns.

Behaviorist theories applied to educational problems

He applied his behaviorist theories to the problems of education. Watson claimed that education should be a conscious process of proper conditioning; the child should be subjected only to desirable stimuli. The same approach to the problem of education had been made by the French philosopher Jean-Jacques Rousseau in his educational treatise EMILE (1762). Rousseau, of course, knew nothing about conditioned reflexes; but he, too, had maintained that the child must be subjected only to wholesome influences, or else — a favorite phrase of his — "all is lost."

We realize now that Watson's ideas, like those of Rousseau before him, were oversimplified. They laid too much stress on environment and not enough on the inherited traits that make an individual react in a certain way. Yet Watson's ideas have had great influence — not always good — partcularly in the field of child psychology.

A new approach to psychology was developed soon after World War I by the German psychologist Wolfgang Koehler (born in 1887). While interned during the war, he made some famous studies of apes at the German zoological station at Tenerife, in the Canary Islands. Koehler set up problems for apes that could not be solved by simple trial and error but that involved quite complicated mental proc-



A famous psychological experiment conducted by Wolfgang Koehler. A bunch of bananas was hung high up in an ape's cage; a stick and box were put on the ground. The ape put the box under the fruit, picked up the stick, stood on the box and knocked down the bananas with the stick. According to Koehler, the experiment showed that the ape was capable of constructive reasoning.

Wide World

WOLFGANG KOEHLER

esses. For example, a piece of food would be hung up too high for an ape to reach; a stick and box would be put on the ground in his cage. Sooner or later, the ape would solve the problem of how to reach the fruit by putting the box under the fruit, picking up the stick, standing on the box and knocking the fruit down with the stick. Koehler maintained that there was nothing hit or miss about such a procedure but that it showed constructive reasoning.

Koehler was one of the prime exponents of the school of what is called Gestalt, or pattern, psychology. According to this theory, things or ideas can be perceived or understood only in relation to the whole pattern of which they form a part. One's personality is not simply the sum total of many independent traits, for none of these traits is truly independent. They exist only insofar as they form a definite pattern. The individual's whole outlook on life is based on his particular pattern, or mental set or general attitude. The Gestalt point of view is strikingly illustrated in the following anecdote. A little boy was taken to a circus and saw a zebra there for the first time. "Mamma," he asked, "is that a white horse with black stripes or a black horse with white stripes?" The answer, obviously, would depend on the particular mental set, or attitude, with which one approached this "problem."

Progress in scientific psychology led men to ask whether it is possible to measure intelligence. The French psychologist Alfred Binet (1857–1911) was convinced that one could. Collaborating with Theodore Simon (born in 1873), he worked out an ingenious series of intelligence tests in 1905. These consisted of a series of problems and questions, which could be answered only by the exercise of "general intelligence." The tests were so graded that the easiest could be solved by the average

3-year-old, while the most difficult ones taxed the ability of average adults. If a 12-year-old could not pass any test more difficult than that set for average children of 9 years, his mental age was given as 9 and he was considered to be retarded. If, on the other hand, a 9-year-old succeeded in passing the tests set for 12-year-old children, he was classified as of mental age 12, and he was considered to be superior.

The idea of intelligence testing quickly took hold in the United States and became all the rage in educational psychology. The Binet-Simon test and scales were the springboard from which Lewis M. Terman (born in 1877) and his colleagues at Stanford University jumped into large-scale measuring of intelligence. Terman adopted a suggestion made in 1912 by the German psychologist Wilhelm Stern: that is, that a child's mental rating could be established by dividing his mental age by the chronological age (his age in terms of years). This gave his intelligence quotient, or IQ, as it has since been called. IQ is expressed in terms of percentages. If a child of ten takes a Binet-Simon test and passes the intelligence tests for the fifth year but not those for the sixth year, his mental age is 5. His mental age divided by his chronological age is 5/10, or ½ or 50 per cent; his IQ is 50.

The United States Army went in for intelligence testing on a mass scale in World War I. The tests were used to sort out army recruits of varying levels of intelligence for promotion, discharge, special traning and so on. Since that time it has become increasingly apparent that IQ ratings are open to many objections. It has been shown that mental ability, as translated in terms of IQ, changes with age, with social environment and with many other factors. As a result, psychologists no longer place as much reliance as before on mass tests of mental ability. However, mental tests are still considered useful if they are administered by trained psychologists, who know how to evaluate the results properly.

We have indicated in this brief discussion only a few of the notable figures in

Child Development Clinic, Yale Sch of Med.

A psychological test at the famous Child Development Clinic of the Yale School of Medicine.

Child Development Clinic, Yale Sch. of Med.

The noted child psychologist Arnold Gesell examining the behavior of an infant in the photographic dome of the Child Development Clinic at the Yale School of Medicine. The dome is equipped with concealed motion picture cameras and it is encased by a one-way vision screen. The screen conceals the observers who are stationed outside the dome.

the history of modern psychology. There were many others. The German Hermann Ebbinghaus (1850–1909) set the stage for most later work on the subject of memory. He also engaged in many experiments based on the memorization of nonsense syllables. He claimed that such experiments made it possible to analyze accurately the higher mental processes — a claim that is now considered rather doubtful.

Gustave Le Bon (1841–1931), a French physician and sociologist, wrote an interesting treatise THE PSYCHOLOGY OF CROWDS (1895). He claimed that the mentality of a crowd, considered as a whole, is lower than that of the members of the crowd when they act as individuals. There is much acute observation in Le Bon's work, though his method is descriptive rather than experimental.

Henry Herbert Goddard (born in 1866), was one of the first students of mental deficiency; he is credited with the coining of the term "moron" to describe the highest grade of the feeble-minded. Goddard was for many years the director of the Vineland (New Jersey) Training School, an institution for the feeble-minded. At Vineland, Goddard furthered the policy of preparing mentally retarded children, as far as possible, to take an active and useful part in the work of the community.

The Spaniard Santiago Ramón y Cajal (1852–1934) succeeded in isolating the neuron or nerve cell. He also found new ways of staining nerve tissue with dyes for study, and he studied the structure and connection of nerve cells in the gray matter of the brain and the spinal cord. He received the Nobel Prize in physiology in 1906 for his accomplishments. Another Nobel Prize winner, Sir Charles S. Sherrington (born in 1861), worked out many of the functions of the neuron. He did a good deal of pioneer work in the study of receptors — cells or groups of cells that receive stimuli.

The child specialist Arnold Gesell (born in 1880) did remarkable work in child psychology at the Yale Psycho-Clinic (later called the Child Development Clinic of the Yale School of Medicine). He founded this clinic and also served it as director. In the early part of his career, he devoted himself to the study of back-

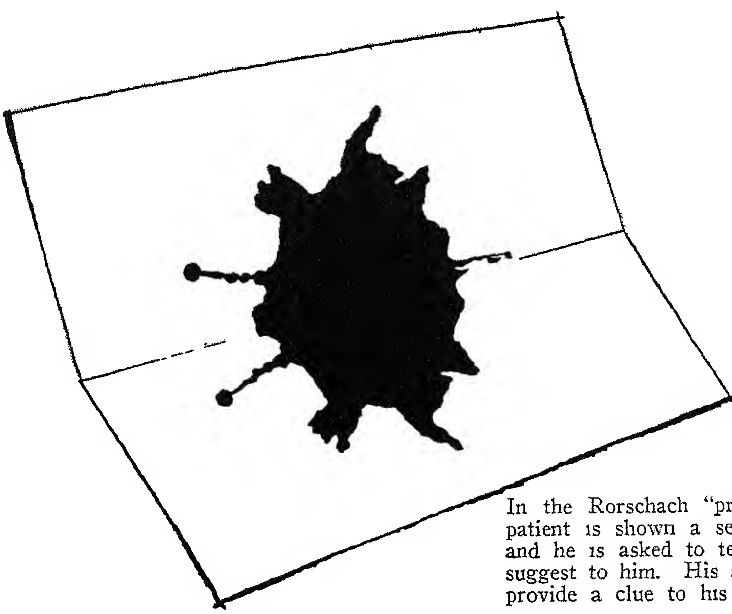
ward children; but he became chiefly interested, after a time, in the mental development of the normal child from birth to school age. He believed that the mental growth of the child reveals itself "in consistent and characteristic behavior patterns, governed by laws of growth similar to those which control the development of his body." The principal instrument in the Child Development Clinic was the motion-picture camera. By means of an ingenious screen device, children were watched without their knowledge, and moving pictures were made of every phase of their activities. These records were then assembled in a Photographic Research Library.

So-called projector tests for investigating personality structure were developed in the twentieth century. The most famous of these is the Rorschach test, named after the Swiss psychiatrist Hermann Rorschach (1884–1922). The patient who takes this test is shown a series of ink blots and asked to describe what he thinks they look like. What he sees in ink blots reveals in part what is in or on his mind.

Some psychological investigations have led to rather strange bypaths. For example, the Society for the Study of Psychical Research in London seriously investigated in the 1890's the reported presence of ghosts and other weird psychic phenomena. In the present century, Joseph B. Rhine (born in 1895), an American professor of psychology at Duke University, published a number of studies in what he called extrasensory perception — a technical term for clairvoyance and telepathy. (Clairvoyance is the power of discerning objects that are not present to the senses. Telepathy represents apparent communication from one mind to another otherwise than through the senses.) Extrasensory perception (or ESP, as it is often called) aroused considerable public interest at one time. The testing of extrasensory perception by means of special ESP cards became a parlor game. The validity of Rhine's experiments is still a matter of dispute.

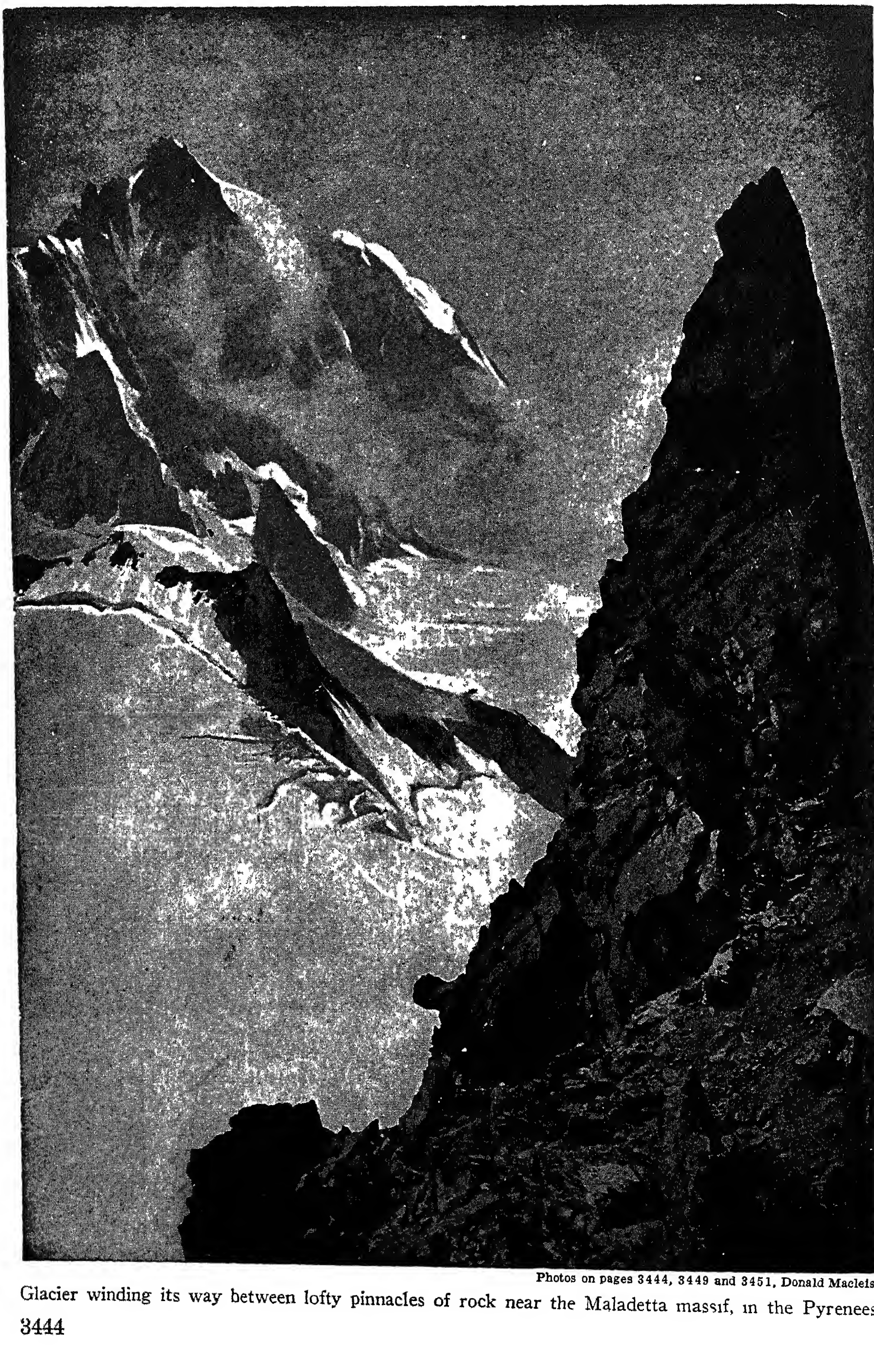
Most of the valid psychological research of the twentieth century was influenced by the work of the towering Austrian genius Sigmund Freud. He opened new paths for human inquiry with his revelation of the subconscious mind. We shall tell his story in the next chapter of SCIENCE THROUGH THE AGES.

SCIENCE THROUGH THE AGES is continued on page 3482



In the Rorschach "projector" test, the patient is shown a series of ink blots, and he is asked to tell what the blots suggest to him. His answers may well provide a clue to his mental condition

A GIANT RIVER OF ICE



Photos on pages 3444, 3449 and 3451, Donald Macleish

Glacier winding its way between lofty pinnacles of rock near the Maladetta massif, in the Pyrenees

THE SOLID WATERS

The Crystallization of Snow and Ice; the Flow of Glaciers and the Formation of Icebergs

DO THE WORLD'S ICE RESERVES LESSEN?

ONE of the most remarkable things about water is the facility with which it changes from vapor to liquid, from liquid to solid We have already discussed its properties as vapor and as liquid; let us now consider its behavior as a solid.

Almost all substances, as we know, contract in bulk as they diminish in temperature, and water down to a certain point does the same From 212° F to 39° F. water shrinks as it cools, but below that point it expands as it cools, and at 32° F it changes into solid crystals, with a further increase of 8 per cent in its bulk. If a pail filled to the brim with water weighs 10 pounds, the same pail filled to its brim with ice will weigh only 9 16 pounds Since the water expands as it freezes, and since ice, bulk for bulk, is lighter than water, it follows that ice is formed first on the surface of water, and that ice floats in water Even a mountainous iceberg will float, and on account of the inclosed air bubbles about one seventh instead of one ninth of its bulk will be above water.

The importance of this we have already mentioned. Did water not expand but contract on cooling, did ice not float, then ice would be formed in the first place at the bottom of water. Accordingly, since water is a very poor conductor, and since warm water does not sink, the heat of the summer sun would not reach the ice in the depths. Winter after winter would add layer on layer of ice, and eventually all the water in the world would be solid ice The climatic and biological results of this are evident, and it is plain that the anomalous behavior of water in expanding before and during freezing is of great advantage to the world as a habitation of living things

At freezing-point, as we have said, water becomes converted into solid crystals, and these crystals, according to circumstances, may form ice or snow. The crystallization of water on passing from the fluid to the solid state is no unique phenomenon; indeed many substances are commonly found in a crystallized state, like sugar, salt, sulphur and alum The size of any crystal is of no importance, the same substance may exhibit microscopic and huge crystals Quartz crystals, for instance, are found so small that they can be seen only through a microscope, and so large that they may weigh over a hundred pounds And any minute crystal will grow indefinitely in size by a deposition of more substance on its exterior The important and distinguishing feature of crystals is not their size but their shape, and especially their interfacial angles, that is, the inclination which one facet bears to another.

The crystals of snow are known to everyone Who has not caught snow on his sleeve to examine the delicate rays of the crystal against a dark background? On examination it will be found that there are numerous varieties of snow crystals, yet each is regular and symmetrical, and each has six rays or angles, neither more nor less W. A Bentley, of Jericho, Vermont, has photographed more than a thousand different forms of snowflakes, but all of them belong to the same crystalline system.

Ice, like snow, is crystalline in structure; it is made up of crystals interlocked and interlaced. We cannot see the individual crystals in solid ice, but if a block of it be melted with a burning-glass it will be found that the melted crystals leave little spaces shaped like tiny flowers, each with six petals. In the beautiful ferny patterns traced by the frost on our window-panes it is easy to demonstrate the crystals. Even hail can be shown to consist of crystals.

The part played in the economy of nature by solid water is a very important one In many parts of the world snow and ice are perpetual, and occur in such large quantities that they may quite legitimately be considered as crystalline rocks In the Arctic regions there is constant snow and ice, and even in tropical and sub-tropical countries, at a certain height above sea level, snow and ice last the whole year round.

The level above which snow persists, the "snow-line", varies with the latitude and with other circumstances. On the north side of the Himalayas it is about 16,600 feet; in the Andes of Peru about 15,500 feet; in the Alps, about 8500 feet; and in the northern Norwegian mountains, about 3000 feet up.

What should we see on a mountain fifty thousand feet high?

But the snow-line varies from place to place on the same mountain range, and from year to year on the same peak. Probably if a mountain rose to 50,000 feet or so, it would have little or no snow on its summit, since all the moisture of the atmosphere would be condensed before it had risen so high. In the Alps, indeed, the greater bulk of the snow falls at an altitude of between 6000 and 9000 feet. At the Hospice of Grimsel, which is situated at an elevation of 6048 feet, $57\frac{1}{2}$ feet of snow, equivalent to 5 feet of water, have been recorded during six winter months At the St. Bernard Hospice (8110 feet), the annual depth of snow varied during twelve years from $11\frac{1}{2}$ to $44\frac{1}{2}$ feet At some places 6 or 7 feet of snow have fallen in a single night.

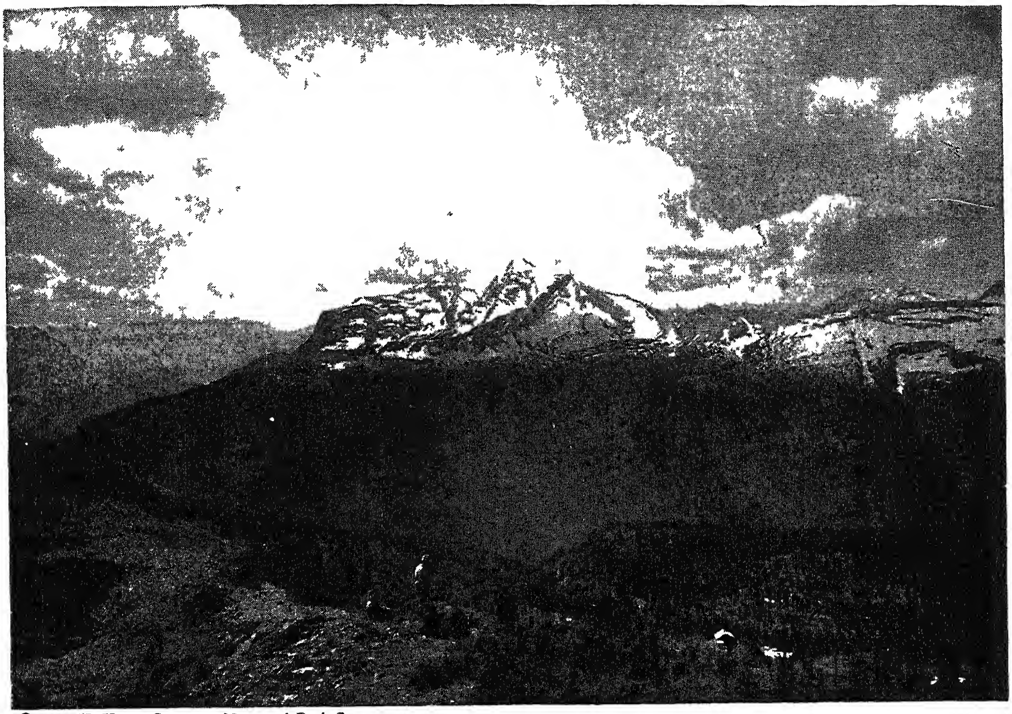
On the average about 30 feet of snow falls every year on the high Alpine peaks Thirty feet of snow annually would in a thousand years grow to thirty thousand feet, if the snow remained and accumulated from year to year But it does not accumulate; it is melted and evaporated by the sun, and it slides down the mountain-sides as avalanches and glaciers.

The ways in which the winter snows disappear from mountains

Rain and mist and wind also serve to dissipate it in various ways. In one day a hot sun or the warm winds, called "*foehn*" or "chinook" winds, can melt over two feet of snow, and a hurricane can remove thousands of cubic feet of snow. It should be noted that snow can be completely removed by evaporation without passing through the liquid state and hence without any appearance of actual thaw All those who ski and toboggan are well acquainted with this slow, steady evaporation of the snow

The masses of snow which slide suddenly down mountain slopes are known as avalanches. Avalanches are of two kinds — "dust" avalanches, consisting of finely powdered, loose snow; and "ground" avalanches, consisting of masses of more coherent snow It is difficult to say which is the more dangerous. Both gather volume and momentum as they descend, and may finally acquire such pace and impetus as to sweep away villages, break away rocks, and uproot trees merely by the blast of compressed air which precedes them. An avalanche from the Pyrenees in 1846 leveled more than 15,000 pine-trees.

Were it not for trees on the slopes of mountains, avalanches would work still more havoc, and many plantations are specially set out for purposes of defense So important as natural defenses are the trees that at one time any man found guilty of destroying a tree in the valley of Andermatt was put to death; and it was popularly believed that drops of blood oozed from any branch intentionally broken, a superstition alluded to by Schiller in his "Wilhelm Tell".



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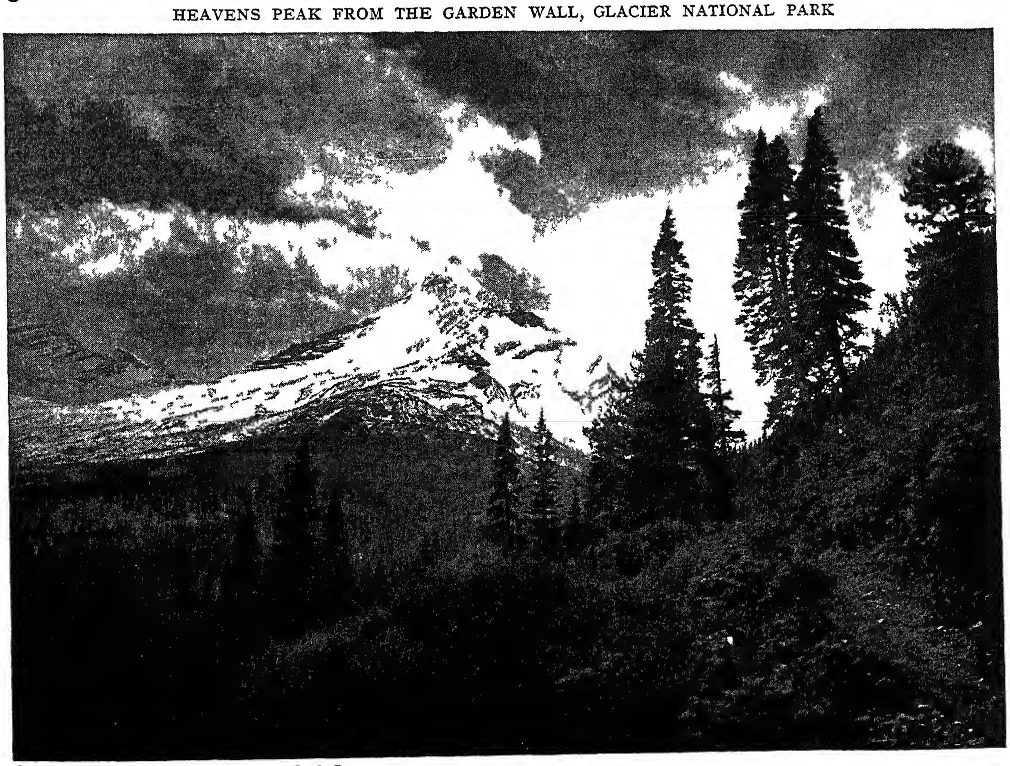
HEAVENS PEAK FROM THE GARDEN WALL, GLACIER NATIONAL PARK



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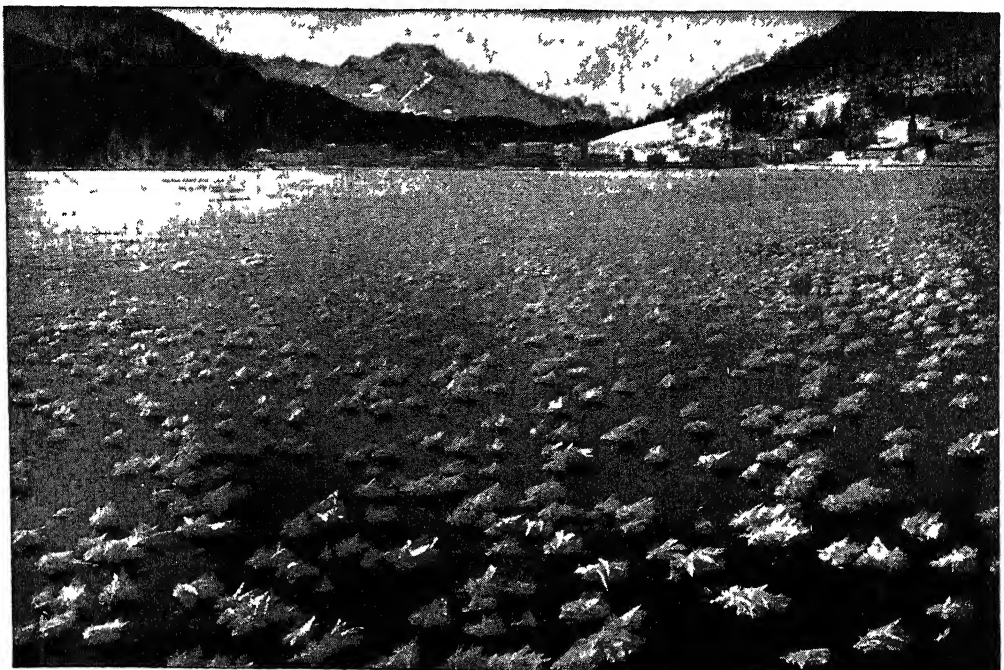
MOUNT JACKSON (10,023 FEET), GLACIER NATIONAL PARK

In places subject to avalanches, man, besides planting trees, has usually erected walls and basket works. But all snow that slides down a mountain does not do so suddenly and violently as an avalanche More commonly it moves slowly downhill, becoming more and more compressed as it descends. At first the snow consists of loose, frozen granules, then the granules are compressed into a compact mass known as "*névé*" or "*firn*", and eventually the mass is converted into blue, compact glacier ice The change of snow into ice is mainly a matter of compression — a change and the pressure of the mass above and behind them In 1827 a hut was built on the Unteraar Glacier and its position marked; in 1841 it was found to have moved 1561 yards down the valley, or at the average rate of 112 yards a year The Finsteraar and Lauteraar glaciers, tributaries of the Unteraar Glacier, were found to have a central flow of about 80 yards a year. The Mer de Glace on the slope of Mont Blanc, near Chamonix, France, moves much more rapidly At the base of the Montanvert its rate is 822 feet annually, and its mean daily rate



ICE-FLOWERS ON ST. MORITZ LAKE, FORMED BY THE THAWING AND REFREEZING OF ICE

of much the same nature as that of the snow on our heels into lumps of ice.

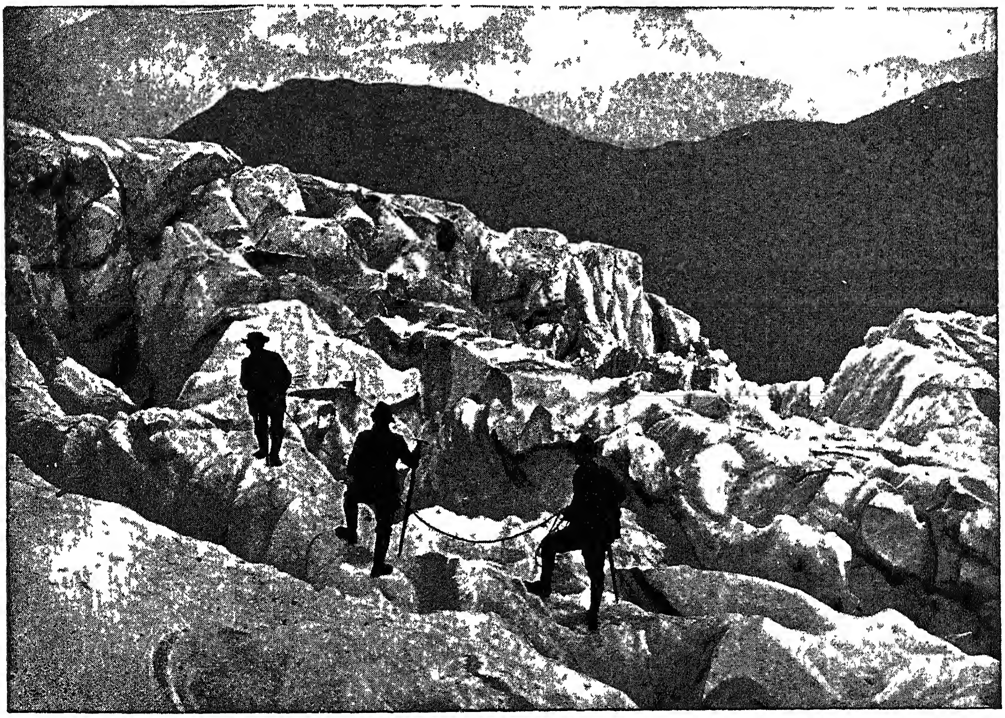
Though the snow in the course of its descent is converted into glacier ice, the ice is not stationary; the whole glacier flows downwards like a river. If a row of stakes be planted in a line across a glacier, it will be found that the stakes will slowly be carried along downhill, the central stakes moving more quickly than the lateral ones; showing that, just as in a river, the flow of a glacier is quickest in the middle. Different glaciers flow at different rates, depending on the slope of their beds

in summer and autumn is from 20 to 27 inches at the middle, and 13 to 19½ inches at the sides. Faster still flow the glaciers from Greenland's icy mountains. One at Jakobshavn Fiord was found during the summer to advance at the rate of 65½ feet a day, and another flowing into the sea at the bay of Angpadlartok at no less than 100 feet in 24 hours.

On several occasions the rate of flow of glaciers has been demonstrated in dramatic fashion by the recovery of the bodies of men who have fallen in the clefts of a glacier.

In 1820 three guides fell into a deep crevasse in the Glacier des Bossons, which only in 1861, 1863 and 1865 gave up their bodies. In the interval it was found that they had traveled about $3\frac{3}{4}$ miles, or about 160 yards each year. In 1860 an Austrian glacier gave up a corpse clad in a garment centuries old, showing how long it must have lain in its icy embrace It must be understood, however, that no glacier flows at the same rate from top to bottom, but that its rate of flow varies like that of a river, and for the same reasons.

The movement of glaciers is more probably explained by the fact that ice melts under pressure, to freeze again when the pressure relaxes According to this theory ice is successively freezing and melting, fracturing and mending A simple experiment, often used, illustrates the melting of ice under pressure, and its regelation when the pressure is removed A heavy weight is slung over a block of ice by a loop of wire. The pressure of the weighted wire melts the ice under it, and as the wire cuts through the ice the pressure it exerted is removed above it, and so the melted ice freezes again; and when the wire has gone right through the block the latter is found unbroken.



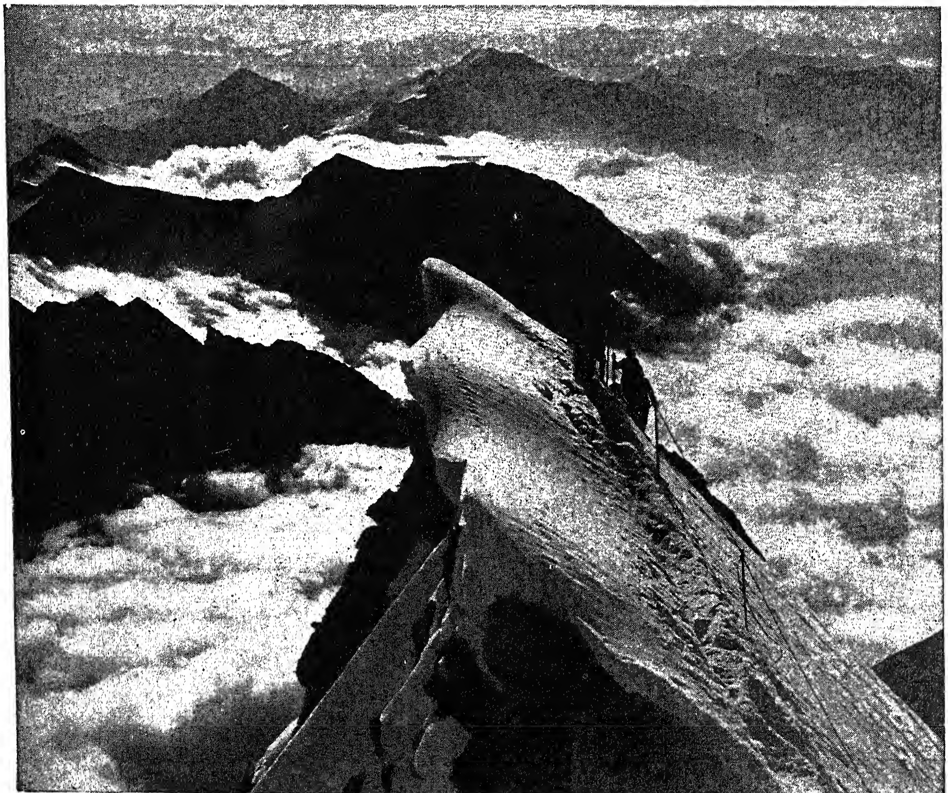
TRAVELERS ON THE BOSSONS ICE-FALL

It is rather a remarkable thing that a mass of hard blue crystalline ice should actually flow like a river, and the nature of the flow is not yet fully understood. It was formerly supposed that ice is a plastic substance, and that under tremendous pressure it would flow as resin or pitch might, accommodating itself to the irregularities and inequalities of its bed. This viscosity theory is more difficult to believe when we consider that glacier ice is really composed of grains of ice from the size of a pea to the size of a melon, and is not a homogeneous mass.

Though the glacier travels with a kind of flowing motion, it never preserves entire continuity. Always stretching obliquely from the margin towards the middle of the stream, there are fissures known as "crevasses". At first these fissures point upstream, making an angle of 45° with the bank, but the movement of the glacier soon disturbs their original direction, and may eventually produce an irregular network of crevasses.

The fissures, moreover, are not permanent; they usually soon close up again, though a few may widen and persist as great, yawning chasms, which may be hundreds of feet deep. The intersection of glaciers by crevasses sometimes leads to the formation of fantastic blocks and columns of ice which may resemble animals, or spires, or turrets. The tower-shaped structures are known as "*séracs*". In winter the crevasses are filled up with snow; and when summer comes part of the snow remains, forming bridges, often unsafe, but often useful to mountaineers.

In every country with snow-mountains, glaciers abound. In Switzerland there are no less than 2000, averaging from three to five miles in length. The great Aletsch Glacier is over a mile broad, and nearly ten miles long, and the Gorner Glacier, 9.4 miles long, covers an area of 26.6 square miles. In Scandinavia glaciers are equally plentiful, and in the Himalayas and Andes there are many of colossal size. In the United States there are many in the mountainous regions along the Pacific Coast, especially on the slopes of Mount Shasta, California, and Mount Rainier, Washington. In Glacier National Park, Montana, there are some ninety, and though these are of comparatively small size — the largest having an area of about 3 square miles — they are very fine examples of glacier formation. Larger glaciers are found among the Canadian Rockies, and in Alaska there is the mighty Muir's Glacier, which, with many others, flows into Glacier Bay. Where it issues from the mountains, it is more than 2 miles wide. "Nine large and seventeen smaller branches unite to form the main ice-stream, which to the extent of a current 5000 feet wide and 700 feet deep, enters the sea during the month of August at the rate of 70 feet a day in the center, and 10 feet in the margin."



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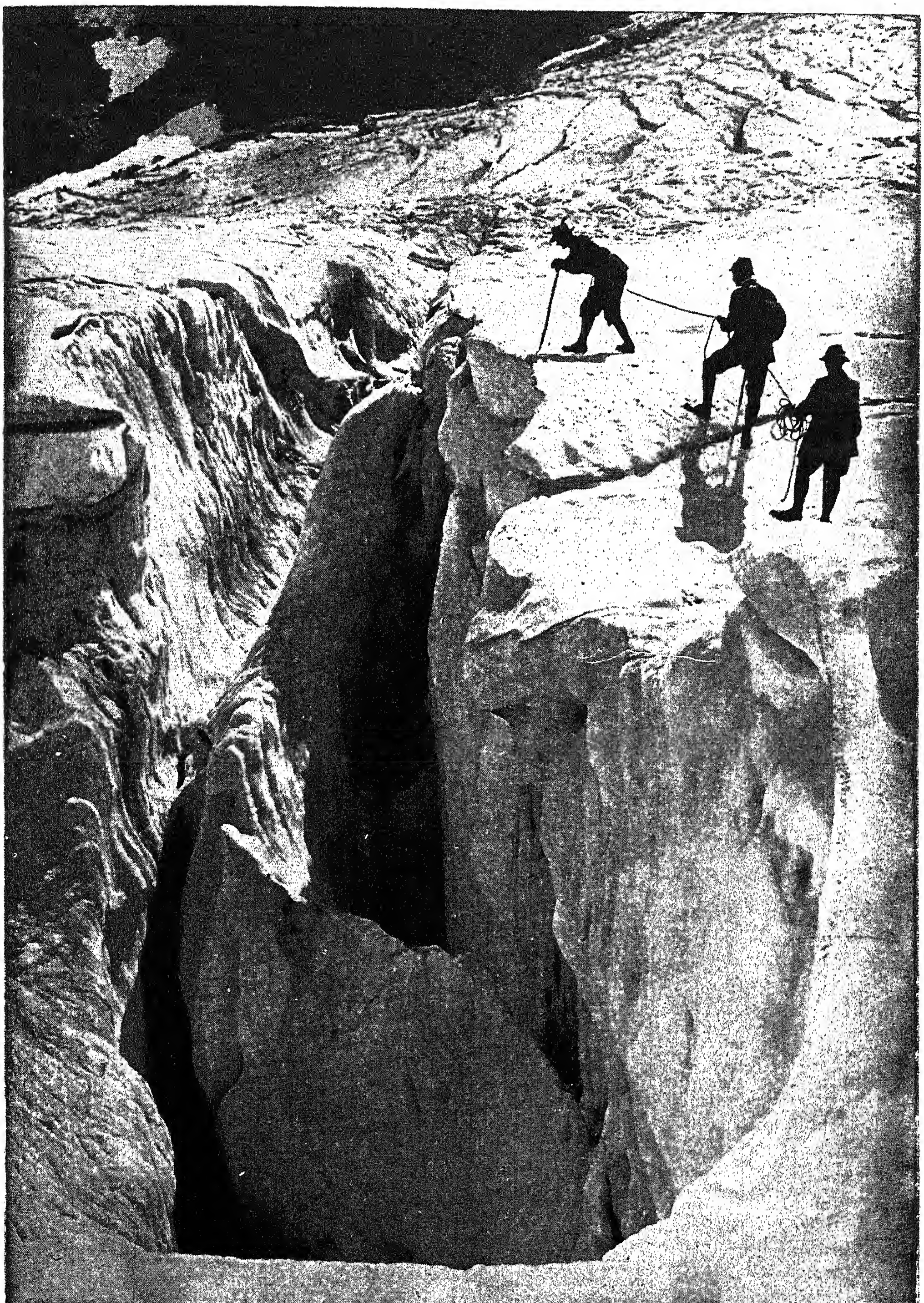
ABOVE THE CLOUDS ON THE CREST OF THE DOLOMITES, AUSTRIA

ICY ABYSSES OF THE MONT BLANC RANGE



A CREVASSE EIGHT HUNDRED FEET DEEP ON THE GLACIER DU GÉANT, NEAR CHAMONIX

A glacier usually ends gradually tapering away as it descends, and from its termination gushes a stream formed partly by the melting of the glacier itself, and partly by streamlets which have poured on to it from the hills and have tumbled down its crevasses. The thawing of the glacier limits its downward career, and during the summer, indeed, it retrogresses and thins out. In Switzerland, the daily average summer retrogression is 3.62 inches, and the daily summer subsidence 1.63 inches. In the winter the glacier lengthens and thickens again.

Are glaciers increasing or diminishing, or do they fluctuate in size?

At this point the question naturally presents itself — are modern glaciers advancing or retreating, increasing or diminishing? No certain answer can be given to this question. In most cases there has been an alternate advance and retreat, increase and diminution. For instance, in Switzerland, where they have been long under observation, they retreated during the middle decades of the last century, advanced again during the last decades, and now seem to be retreating again.

Between 1854 and 1869 the Glacier des Bossons receded 332 meters, that of Bois 188, that of Argentière 181, and that of Tour 520. Between 1871 and 1875 every Alpine glacier receded. In 1875 a pretty general advance began, and during the last few years of the century the Glacier des Bossons advanced at a rate of over 160 feet. In 1899 the advance began to halt, and at present all over the globe, with few exceptions, glaciers are receding.

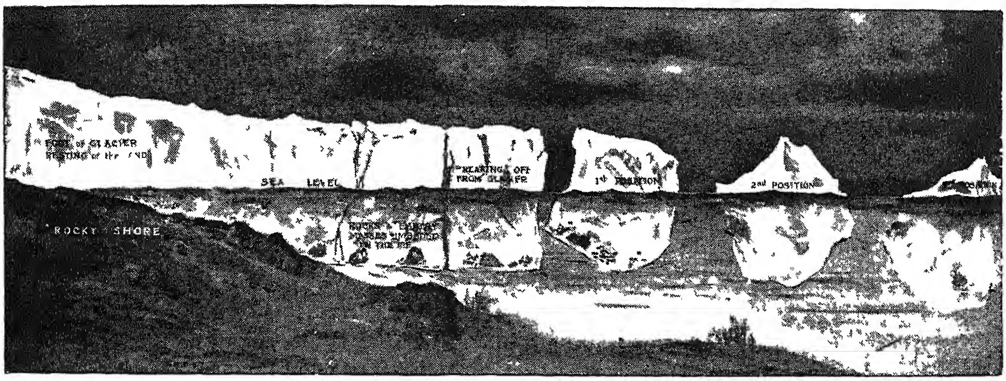
The enormous size of polar glaciers and ice barriers

In certain respects, the polar glaciers form a class by themselves, in that they flow into the sea, and break up into icebergs. Some of them are of huge size. The Humboldt Glacier, in North Greenland, has a frontage of 66 miles. The Dove Glacier in the same region is about as large, while the Eisblink pushes a tongue of ice 13 miles long into the sea. The whole of the antarctic continent, a continent as large as Europe and Australia combined, may be considered a glacier or a congregation of glaciers, for it is covered with the accumulated snows of centuries which have been turned into ice by pressure; and the ice by its own weight is slowly and constantly slipping into the sea. The great Ross Barrier, south of New Zealand, shows the character and constitution of the continent. It is a great white cliff of ice, sometimes reaching 100 feet in height, which stretches east and west for a distance of 300 miles. Though not resembling a typical tongued glacier, this great wall of ice is in fact and act a glacier, since it is constantly flowing onward, impelled by the weight of ice behind it. One great feeder is no less than 415 miles from the sea.

When the ice of a glacier reaches the sea it usually creeps at first along the sea bottom, but after a time its superior buoyancy forces it upwards, and under the strain the glacier fractures, and a great mass of ice is broken off, and floats in the sea as an iceberg.

An iceberg large enough to block up half of Long Island Sound

Icebergs are stupendous. Those broken off from the Jakobshavn ice-field in North Greenland sometimes rise over 600 feet above the sea, which means that the total height of the iceberg from base to summit is about 4000 feet. Hayes measured an iceberg 315 feet high above the water, and more than three quarters of a mile long, and calculated that it weighed 2,000,000 tons. Ross and Parry described one 153 feet high and $2\frac{1}{2}$ miles broad, which might weigh about 1500 million tons. The antarctic icebergs are not so high as the arctic, but some are of enormous extent. William Speirs Bruce, the leader of an antarctic expedition in 1902–4, declares that he saw many icebergs at least a mile long, that on one occasion he measured one 12 miles long and that "on another occasion the *Balæna* steamed at the rate of five knots for six hours along the face of a berg, which made the length of it fully 30 miles."



HOW ICEBERGS BREAK AWAY FROM A GREENLAND GLACIER

Such enormous masses of ice may float for great distances before they melt. Icebergs from Greenland may get as far south as the coast of Spain, and those from the antarctic glaciers may get as far north as the Cape of Good Hope. The number that cruise about the sea must be very great. In Baffin's Bay, Dr. Kane once counted a pack of 280 bergs. Dr. Bruce counted 60 from the deck of the *Balæna.* During the winter of 1903 a constant procession of icebergs drifted past the South Orkneys for eight months.

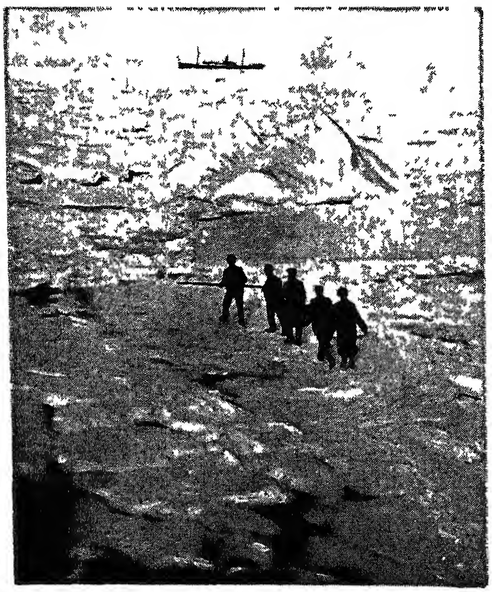
Even in the track of the great North Atlantic liners icebergs in great numbers may be seen during certain months of the year, and many a good ship has been ripped and wrecked by the mighty ice crags. South of Newfoundland the floor of the ocean must be littered with ships and dead men's bones, for here, in the mists that hang around these regions, many ships have gone to their doom. Here the *Titanic*, April 14, 1912, collided with an iceberg and was lost, with 1517 out of the 2223 on board.

Dangerous and formidable as they are to the mariner, icebergs have a beauty, a grandeur, and a solemnity that appeal to the beholder. "Their stupendous size," says Dr. Bruce, "their exquisite architectural composition, more magnificent than the temples and pyramids of Egypt, more overpowering in solemnity than the Sphinx, make the most thoughtless think for a moment of the Power that controls the forces of nature. At one time we passed through a regular street, lined on each side with towering bergs, each a temple in itself, now Doric, now Egyptian, each perfectly carved and shaped, each purer and whiter than the other, glittering in the sun, pearl-grey in the shade, and rich blue in the clefts and caves which pierced their sides. This street or avenue was several miles long; indeed, some individual bergs were fully half a mile in length. Side avenues opened into this main avenue."

ICEBERGS FLOATING PAST NEWFOUNDLAND, SOUTHWARD BOUND

Bergs are more dangerous to mariners when they are massive and unmelted, but even when they are melted down to fractions of their original selves they remain perils of the deep The final remains are known as "growlers" and "bergy bits". They are particularly hard ice, and many is the good ship they have ripped up. Bergs and bergy bits are also indirectly dangerous, in that they condense moisture and cause sea-fogs.

Besides the ice formed from snow by compression, there is, of course, ice formed directly from water by the action of frost.



ICE-FLOES OFF THE COAST OF LABRADOR

In some latitudes the rivers, lakes and inland seas freeze in winter and thaw in summer; in other latitudes there is frozen water all the year round. Examples of the first sort are seen in the Siberian rivers, in the Baltic, and the St. Lawrence with its lakes. Examples of the latter sort are seen in the arctic and antarctic regions.

In Canada the ice on the lakes and rivers is one and a half to two and a half feet thick. When river ice breaks up, it rends and tears the banks of the river, and wears down any islands in the middle of the stream. Sometimes a river gets dammed up with heaps of broken ice; and when eventually it bursts the dam it may work great destruction.

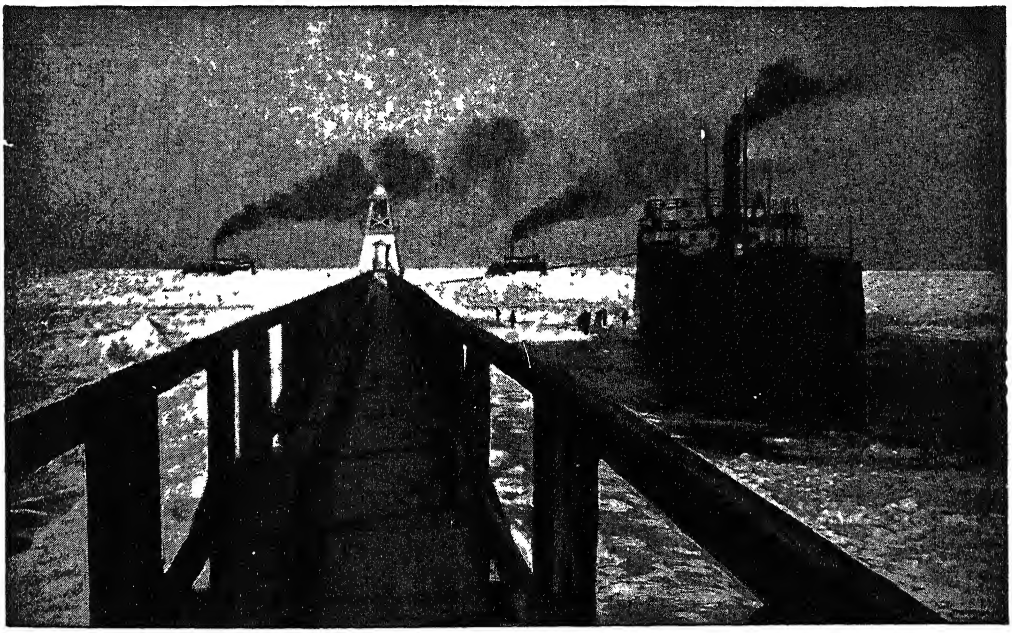
As a rule, ice forms on the surface of rivers, but sometimes on the bottom The reason of this is supposed to be that the cold water of the surface is mixed by the currents into the general body of the water, and so the river is uniformly cooled down to freezing-point. That being so, the stiller bottom water in contact with cold stones freezes first. This ground ice, sometimes known as "anchor-ice", often floats to the surface, and lifts with it stones, gravel, sand and other materials to which it is attached.

The ice formed on the surface of the sea is of special interest. Not till the temperature falls to 28° F. or thereabouts does the sea freeze, and when it does it forms an ice differing in many ways from land ice If the surface of the open sea be observed when the temperature falls to 29° F and lower, it will be found to be overspread with delicate spicules; and if the temperature keeps low these will increase until they form a layer two or three inches deep. A layer of fresh-water ice two or three inches thick is strong enough to skate upon but a layer of sea ice of the same thickness is soft like glue, and will not bear a child; in fact, a seal can easily poke its nose through, and an ordinary ship can plow through it. If snow falls upon such a layer, the ice spicules and snow crystals lock together, and the depth of the layer is increased; and very often the earliest layer of ice on polar seas is of this mixed nature. It is known as "bay ice", since ice is formed first in sheltered bays, or "black ice", because it is black and translucent.

Naturally such ice is fragile; and soon, under the heaving of the tides and the threshing of the winds, it is broken into hexagonal fragments a few inches or feet in diameter. These hexagonal discs again get crushed and knocked about, and thicken with the frost, and become what is called "pancake ice". The pancakes, again, get frozen together into a rough, tessellated pavement, and this, in turn, is broken into bigger hexagons, which again are congealed together. Finally a pancake patchwork of thick, white ice is formed strong enough to resist the

efforts of the sea to break it. If the sheet is large it is called "floe ice"; if it extends continuously farther than the eye can see, "field ice". But a distinction must here be made. This is floe ice or field ice of the first season — débutante ice, so to speak. But floe ice and field ice are not always formed *de novo* out of sea water; they may be formed out of fragments of the former winter's new ice when it breaks up in the summer. In this case, when the floe ice or field ice is not born of bay ice, but built up out of fragments of former floe ice or field ice, it is much rougher and stronger

When sea water freezes the ice is found to have rejected about four-fifths of the salt which was originally present; and though there may be some brine on the surface, the ice below when melted is almost pure water, and is quite good for drinking and washing purposes Almost all antarctic ice has a yellowish-brown layer sandwiched in it just about sea level Pack ice, floe ice, berg ice — all show this colored layer In arctic ice the same layer occurs, but it is more superficial When examined it is found to consist of myriads of microscopic plants called "diatoms", which make the ice their home.

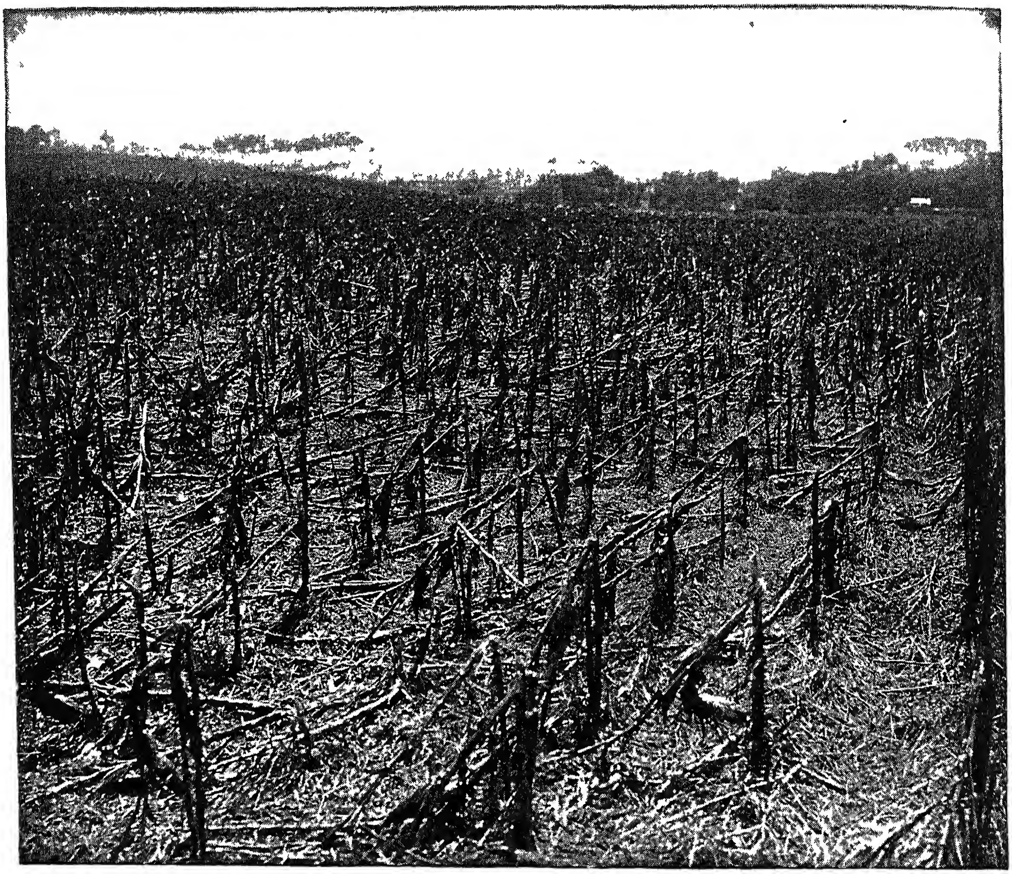


BOATS PLOWING THEIR WAY THROUGH THE ICE-STREWN WATERS OF LAKE MICHIGAN

When fields and floes break up they first fracture into small floes, but these again split up into fragments mostly a few feet in diameter. In this condition the ice is known as "pack ice". Pack ice drifts before the wind in mighty streams with irresistible power until the separate pieces are again welded by frost into fields or floes. Often the pieces are hurled together in heaps; and when they freeze together we get what is known as "hummocky ice". Round the margins of pack ice there is usually a collection of much smaller fragments, known as "brash ice".

Since the layer spreads for hundreds and hundreds of miles, it represents a tremendous population of diatoms. Curiously enough they serve as protective coloring for the polar bears, which in their winter pelage are a light yellow, closely resembling the color of this layer, and, even at a moderate distance, hardly to be distinguished from it.

In some parts of the polar regions, especially in Spitzbergen and Nova Zembla, acres of snow and ice are colored red. This is due to the blood-red microscopic alga *Sphærella nivalis*.



DISASTROUS EFFECTS OF HAIL

Photograph of a corn crop almost completely destroyed by a hail storm which covered an area about 20 miles long by 3 miles wide.

It is remarkable that, even in ice, life should survive. Dr. Bruce melted pieces of wet soil and moss that had been subjected to a temperature of −45° F. and as soon as they were melted myriads of minute creatures sprang into activity, and "a small nematode worm, that had evidently been on the point of laying its eggs when overtaken by the frost months previously, began to lay them as soon as it had melted out, and continued its life as if nothing had happened during this long period of sleep".

Hail may be briefly mentioned. It consists of little particles of ice which fall from the upper atmosphere. Hail falls in summer rather than in winter, and by day rather than by night, and is difficult to explain. It is probably formed of raindrops which have been carried up into the colder higher regions of the atmosphere, and frozen there. Though usually about the size of small shot, hail may occur in pieces several inches in diameter, and a hailstorm in such a case may do great damage to fields and flocks, especially as hail falls in its more destructive forms only in the summer, when the crops have reached a stage in which they are easily damaged. Often hailstorms are accompanied by violent winds, which add to their dangers. It has been calculated that the damage done by a single storm, of unusual dimensions and persistence, has amounted to four or five million dollars; and in the course of such a storm stones weighing as much as three pounds apiece have been precipitated from the sky.

ON THE MICROBE'S TRACK

The Fascinating Life and Work of the World's Greatest Chemist: Louis Pasteur

MAN'S SUPREME PHYSICAL BENEFACTOR

WE now come to the name of a great man, seldom thought of as a biologist, to whom, nevertheless, the science of life is immensely indebted, and who must certainly rank beside any of those whose work we have already discussed. Similarly, we shall find that Louis Pasteur must rank with or above the greatest doctors of all time, though he was not a doctor. He holds a place apart, at the foundation of many modern sciences, for none of which was he educated or specially prepared. For he began life as a chemist, and all his subsequent researches really spring from a chemical view of the problems of biology and medicine.

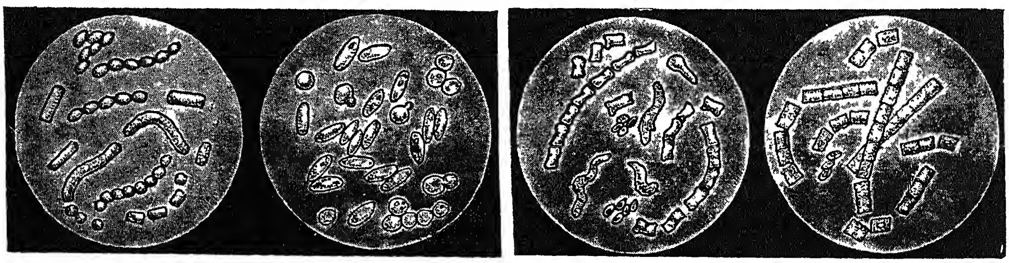
Early in our study of life we saw that there are processes of fermentation which play a large part in it, but how large no one can know who has not followed the work of the last few years. There are some who say that "life is a series of fermentations", which is probably true of the physical processes associated with life. Plainly, then, we want to know what fermentation is. When Pasteur began his work the dominant view was that of the great chemist Liebig, who was some twenty years his senior. His theory was that fermentation is a chemical phenomenon, due to certain chemical agents called ferments, probably acting in association with the oxygen of the air.

Then came upon the scene Louis Pasteur (1822–1895), who had been trained in Paris under some of the greatest chemists of the day. His genius for original research showed itself at once in connection with the behavior of crystalline salts of tartaric acid.

Students of optics all know that it is possible to polarize light in such a way that all its vibrations are in one plane, instead of being in all planes at right angles to the onward path of the light. It is found that, when a ray of such polarized light is sent through certain substances, they twist or rotate the plane of the vibrations, sometimes to the right and sometimes to the left. Such substances are called, respectively "dextro-rotatory" and "lævo-rotatory". Ordinary tartrates have no influence on polarized light, and are said to be "optically inert"; but the young Pasteur found that a certain microbe (the familiar word was introduced by him) feeds upon or ferments a solution of tartrates in such a way that they become lævo-rotatory, or left-handed. The solution, he discovered, began by being a mixture of the two kinds, right-handed and left-handed, in such proportions that the ray of light was not rotated in either direction on passing through them But the microbe ferments the right-handed molecules, so that the solution now becomes left-handed This is a true fermentation, and it is effected by a living plant. That was Pasteur's initial discovery; and all the rest, including the triumphs of Listerian surgery and many great things yet to come, are due to it.

Let us briefly note, in passing, what this discovery meant for chemistry itself, for recent developments of it may serve biology as much as anything that we are about to study. Pasteur showed that the molecule of tartaric acid may exist in two forms, exactly identical, except that one is, so to speak, the mirror-image of the other.

They differ, in a word, just as a right hand does from a left. This gives us the idea of chemical molecules as *solid* things, existing in three dimensions, and requiring to be studied from the point of view of their solid shape, as well as of their constitution. Hence Pasteur's initial discovery founded what is now called "stereo-chemistry" — that is, *solid* chemistry — which is beginning to win great triumphs Its aid is essential in the realms of organic chemistry, and without it we could not achieve the synthesis or creation of new compounds, such as "606", and a host of other therapeutic substances It may make all the difference in the world — that a compound is built up on a left-handed rather than a right-handed plan; and once we realize that our chemical processes are a series of fermentations, and that a ferment may destroy a right-handed compound and yet leave its mirror-image untouched, as Pasteur showed, we begin to see light upon many of the problems of disease.



MICROBES THAT BEFRIEND MAN BY PROCESSES INVISIBLE TO HIS EYE

The small microbes at the top of the first circle make milk sour, those below them help in the making of butter and cream In the second circle are the yeast organisms, which make alcohol, in the third circle are the microbes that make vinegar, and in the last those that make cheese

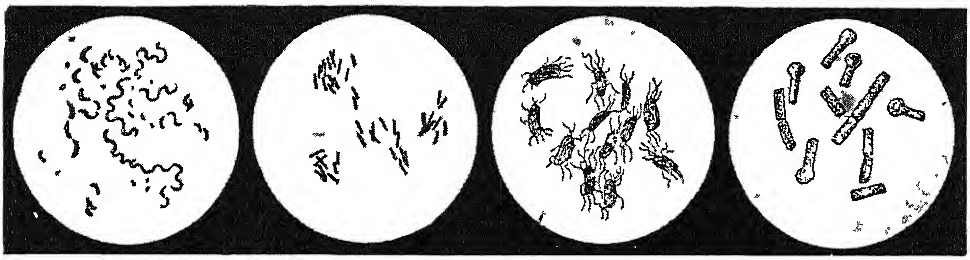
The fundamental fact discovered by Pasteur was, of course, the presence of a living agent in this fermentation. Liebig believed that fermentation was a chemical phenomenon, but Pasteur's work showed that it was a vital phenomenon — a living agent was involved Nowadays, we see that, in a sense, any opposition between these two views was unreal, for we can often extract a chemical ferment, not itself alive, from the bodies of microbes, and can prove that this ferment does its work in the absence of actual life. Thus, the vital theory of fermentation, as upheld by Pasteur, does not really exclude the chemical theory upheld by Liebig. But the cardinal fact remains that these ferments are produced in the body and by the vital activities of a living thing. Fermentation, then, may be due — perhaps is always due in nature — to the growth and life and chemical activity of microbes It is not the air that causes fermentation, though the process may be arrested in materials from which air is excluded. The exposure to air is really exposure to microbic infection, and the fermentation follows Or, if air be necessary for fermentation, it is because air is necessary for the growth of most microbes, but it is the microbes, and not the air, that are really responsible.

To the great alarm of his teachers, Pasteur turned at once from the orthodox paths of chemistry, and devoted himself to further investigation of the ways of microbes. It seemed by no means certain that these microscopic objects really existed or mattered, if they did; and, in any case what possible fruit could be expected from the study of them? But Pasteur held on his way He showed that, while all microbes, like all living things, require oxygen for the purpose of respiration, some obtain it from the air, whereas others cannot live in the presence of air, but obtain their oxygen for respiration by splitting up compounds containing it found in their food. The air-needing microbes he called "aërobic", and the others "anaërobic". The former will grow most abundantly upon the surface of any culture-medium, whereas the latter will grow only in the absence of oxygen and, therefore, only at some distance beneath the surface. A typical instance of the anaërobic bacteria — discovered long afterwards — is the bacillus of tetanus, or lockjaw, which grows in the soil and may thus infect any

chance wound in the hand of a gardener, without relevance to whether or not the wound be in the space between the thumb and first finger, or be made by a rusty nail, as is popularly supposed. But the great majority of wounds infected with soil fail to give rise to tetanus, because the microbe can flourish only in wounds from which the free oxygen of the air has been excluded.

Pasteur soon showed that the change in the optical activity of tartaric acid did not stand alone in being due to microbes. He found that the production of lactic acid, from lactose or sugar of milk, is also due to fermentation by a microbe, the *bacillus lacticus*. He showed, also, that the formation of butyric acid in rancid butter is due to certain bacteria, mostly anaerobic He found the same form in the very important case of acetic acid, which is produced from ethyl alcohol by the action of the *bacillus aceticus*. This was a matter of great practical value. By his study of these processes, occurring in wine and vinegar, he was able to formulate very useful rules for the making of vinegar, and also to give effective directions for the prevention of "wine disease" This last phrase begins to suggest the kind of work to which the latter part of Pasteur's life was to be devoted, for more important things than wine are subject to disease

But first there was a very much discussed problem to which Pasteur's attention was directed and which is certainly a biological problem. This was the question of the origin of life, which we discussed in the second chapter of this section. Here we shall distinguish between the conclusions which were drawn from Pasteur's work, and the work itself. All we are entitled to say is that Pasteur's experiments refuted the supposed proofs of spontaneous generation which many accepted at that time. Materials which had been deprived of life — or sterilized, as we now say — were found to remain as they were indefinitely, provided that no life from outside had access to them They did not ferment, and no life appeared in them, no matter how suitable for the composition or generation of living beings they might be. Hence it followed, and still follows, that if spontaneous generation of life can occur or does occur at the present time, the conditions under which it does so are still unknown.

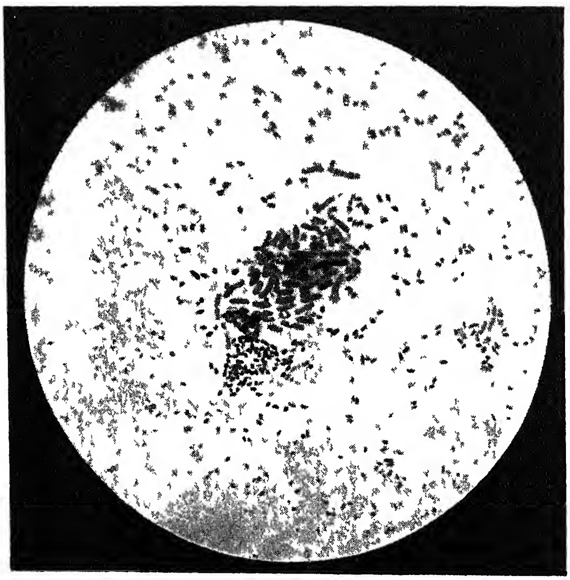


SOME OF MAN'S MICROBE ENEMIES RENDERED VISIBLE BY THE MICROSCOPE

Microbes, often fatal to man and many beasts, are shown enlarged 1,000 times The first are the microbes which cause cholera Koch, in 1883, identified the cholera spirillum as the invisible murderer in this acute, infectious disease The second are the tubercle bacilli which cause tuberculosis In its growth this organism elaborates a chemical product highly poisonous to most animals The third are the cause of typhoid Protection of the food and water supply from contamination, anti typhoid vaccines and bacterins, and control of typhoid "carriers", people who carry the germs though they may not suffer from the disease, have served to reduce the terrors of the bacillus typhosus The last view shows the tetanus bacillus, discovered by Nicolaier in 1884 It is found in surface soil, dust, manure, etc., and often gains entrance into the human body through a cut or wound Antitoxins have been developed which have proved useful in the treatment and cure of this disease

THROUGH SUCCESSIVE STAGES OF REPRODUCTION BY FISSION, ONE MICROBE BECOMES FOUR IN AN HOUR

Not the least useful result of this controversy was the occasion it provided for a great many observations on the vital conditions of microbes. Only by experiment can we ascertain what temperatures microbes will survive or succumb to, and what chemical substances, in what proportions, will arrest their growth, and so act as preservatives of fermentable materials, or, to use the modern term, as antiseptics It was in the course of this work that Pasteur discovered the method of sterilizing milk, known as "pasteurization", which consists in the prolonged use of a less degree of heat than will be effective if used for only a short time.



BACILLI OF ANTHRAX FORMING SPORES

In the 'sixties, after his study of the silkworm disease, by which he was enabled to save one of the most important of French industries, Pasteur began to find that certain microbes are not merely saprophytic but parasitic, living within the tissues of other living creatures, and producing disease. Fowl-cholera matters little to us, but his work upon the anthrax bacillus, which produces the disease anthrax not only in certain lower animals but also in man, was truly epoch-making, for this was the first demonstration of a microbe as the cause of a human disease. Needless to say, the word "cause" has a very definite meaning. Many have asserted, and perhaps some may still survive who assert, that the presence of these microbes of various kinds in various diseases is only an accompaniment or concomitant, but not a cause It might be that the microbe, though certainly parasitic, did not really do any harm, but was merely enabled to grow in the tissues of the host in consequence of the change produced in them by the disease This would conceivably account for the presence of special types in constant association with special forms of disease — in each case the patient's body, on this theory, is made a suitable soil for the growth of some particular microbe. At the stage when the existence of microbes can no longer be denied, and when they are found to be definitely associated with certain diseases this explanation may be advanced

If it be true, of course it reduces the presence of the microbes to an accident of no importance, and the real cause of the disease remains to be discovered in each case. The criticism thus advanced is highly necessary and salutary, for there are many instances where certain forms of microbes seem to be found, perhaps constantly, in association with certain forms of disease, and have been put down as their causes, though the probability is that their presence is secondary and of no importance. This is probably true, for instance, of various microbes which have been described at various times as the causes of malignant growth.

Therefore, when we say that Pasteur found microbes to be the causes of disease, in many instances we require to cite the necessary evidence, which has always been complied with in those cases, such as anthrax, where science now accepts the evidence. First, there must be no case of the disease in the absence of the alleged cause; the association between the symptoms and what is asserted to be the causative parasite must be absolutely constant. The parasite may be quiescent or inert, or its poisons may be so neutralized by the body that the symptoms do not appear.

But if the parasite causes the disease, it must always be found when the disease is present Constant association is thus a necessity for the proof, but it is not enough, for it proves nothing as to causation. The presence of the parasite, as we have seen, may be the effect and not the cause of the disease It is necessary, therefore, to show that the parasite, when introduced into a normal, healthy animal, produces the disease in it This experiment may fail, for the animal may be immune, and no symptoms follow But if the parasite is really the cause of the disease, it will be found to produce the characteristic symptoms, at any rate sometimes, when introduced into the tissues of other individuals of the same species as that to which the first victim belongs We should now be able to recover the parasite from the body of the second victim, and to show that it has multiplied therein, while producing the symptoms we have observed

This may seem sufficient, but even now we have not absolutely proved that the parasite is the cause of the disease In transferring it from the sick to the sound we are, of course, unable to isolate it in such a fashion that no fluid accompanies it Hence, it may be argued that the parasite, thus transferred — we say parasite for convenience, but the number would probably be millions—was not the cause of the symptoms in the second victim, but that they were produced by the really efficient agency of some special poison in the fluid which was taken from the first victim, and which happened also to convey the parasite. That was a theory which required consideration in the past, and must be mentioned now, but it is negatived by innumerable facts which have been ascertained during the past half-century In fact, we shall see that Pasteur's next research was in itself sufficient to show that the parasite, in such a case as anthrax, is really the cause of the disease.

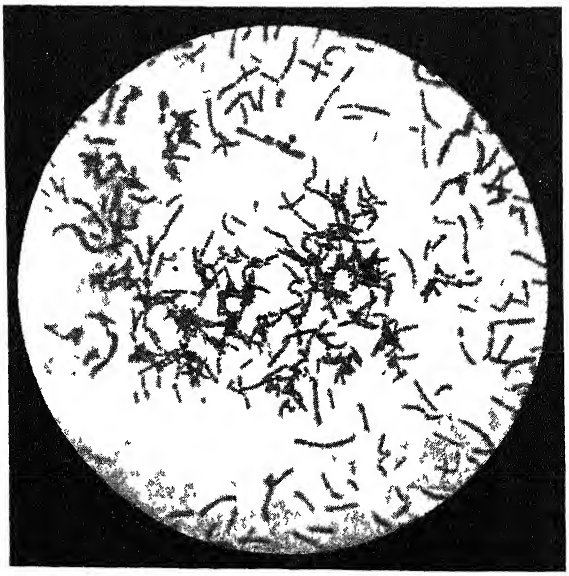
Photo Pierre Petit

LOUIS PASTEUR

Meanwhile, we are to observe the nature of the evidence which science must always require before we can say that a given parasite is the cause of a given disease First, we repeat, the parasite must be found in all cases of the disease This may be no easy matter, for by no means all bacilli are as large and readily detected as that of anthrax In some forms of tuberculosis, for instance, the bacillus of that disease cannot be found, though material from the diseased parts will transfer the disease Here the probable reason is that the bacilli have assumed an involution form or are present in such small numbers that they escape observation in spite of our skill and care in searching for them Second, we must not be disconcerted if we find pathogenic, or disease-producing, microbes in cases where no disease is being produced by them At an early stage in our knowledge, such observations would have been most disconcerting If it has been laid down that a certain coccus causes pneumonia, and a certain bacillus causes diphtheria, what are we to say when these organisms are found in the throats of persons who are in perfect health?

The answer, we now know, is that the accepted use of the words "pathogenic" and "non-pathogenic", as if microbes could thus absolutely be distinguished, is erroneous. We have clear evidence, for instance, that certain "pathogenic" microbes, such as those we have mentioned, may exist in the body and not be pathogenic. We are certain, also, that microbes commonly reckoned non-pathogenic may sometimes take on pathogenic action This complicates our argument, but does not invalidate it. The fact is that microbes may behave in different ways at different times, according to the conditions of their nurture, as we shall see. Further, the soil must be reckoned with.

We now know that, for instance, there are people called "typhoid-carriers", who constantly harbor the typhoid bacillus within them. But for some personal reason they do not suffer from typhoid fever. They are in perfect health; and we might argue, as used so often to be argued, that the case against the so-called typhoid bacillus, as the cause of typhoid fever, therefore breaks down But unfortunately the fact is that if these bacilli, from such a typhoid-carrier, get a chance of invading someone else they promptly set up typhoid fever. If such a typhoid-carrier happens to be a cook, her life-history may involve a long train of hitherto incomprehensible deaths on the part of those for whom she has worked; and only very lately has the strange but simple explanation been worked out.



THE BACILLI OF DIPHTHERIA

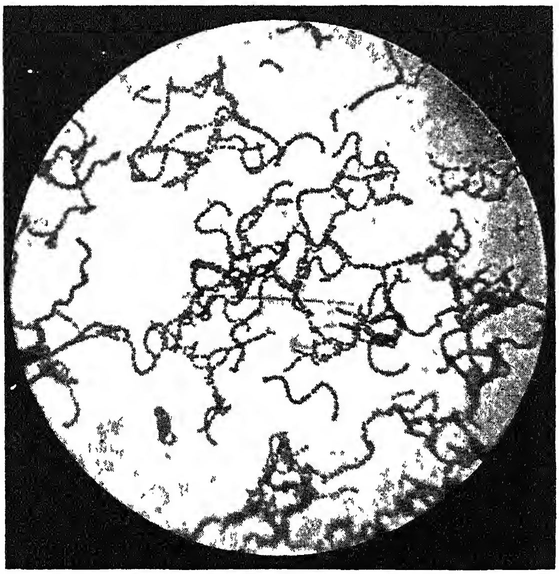
These and many other instances are teaching modern bacteriologists that the supposed distinction between pathogenic and non-pathogenic bacteria must either be abandoned or recognized in a new way. These terms are purely relative to the circumstances A man may harbor pneumo-cocci in his throat for weeks without hurt, and then lie drunk on the road all night, and next day he will be starting with pneumonia The cold and the alcohol have lowered his resistance — whatever that means in terms of exact chemistry — in such a fashion that the formerly innocuous cocci initiate a deadly disease. Henceforth, then, we shall try to realize that the problem of disease production is a complicated one, with many factors, and it cannot be stated simply in terms of the seed, for instance, without any reference to the soil The seed itself, also, offers a host of problems on account of its variability in behavior. Its successive generations follow one another with extraordinary speed, sometimes as often as three times in an hour; and in the course of a short time of exposure to certain conditions, a race or strain that began in a condition of extreme virulence may be rendered quite harmless, or *vice versa*.

We are to understand that these parasites, unlike some of the larger animal-parasites of man, do not produce their effects by their mere presence. Their action depends upon the production of a chemical product which we may call their virus or poison. The question, then, is as to the virulence of any particular microbe, according to the abundance and quality of the virus it produces.

This requires very close study, and it is not enough to judge by effects, for those effects introduce a new factor — the resistance of the new host. Thus a given culture, of a given virulence, whatever that may be, will kill one host in a few hours, and will produce

no symptoms at all in a second Are we to judge of the virulence of this culture by the first experiment or by the second? The fact is that the first host was susceptible; and the second, perhaps having lately recovered from an attack of the same kind, was, for the time being, at any rate, immune. We have to distinguish, then, between results which are due to changes in the seed, and those which are due to the varying conditions of the soil

When we do so, we find that the microbes themselves can be caused to vary widely in virulence, so that they can no longer do any harm to creatures which would otherwise certainly have succumbed. Pasteur himself was the pioneer in these researches, which have already produced tremendous results for the benefit of man and of animals He had no sooner begun his observations on the anthrax bacillus than he proceeded to study the effect upon it of many agencies. This, of course, is work of a kind which can never be finished, for there is no end to the experiments that can be made as to the action of, say, sunlight, radium, Röntgen rays, new drugs, etc., upon all manner of microbes. Pasteur soon found that the virulence of microbes is modified by exposure to air, by the conditions of their nutriment, by varying temperature, etc. Thus if anthrax bacilli be grown at a high temperature for twenty-four days they lose their virulence, and can no longer kill a sheep. This was the basis of Pasteur's method of immunizing animals against anthrax. He injected these attenuated bacilli, as they are called, into a sheep, and in this way such a resistance was somehow acquired by the animal that, when it was inoculated, a fortnight later, with a culture which had been exposed to heat for only twelve days, and was therefore only half as attenuated presumably as the first, the animal did not suffer A fortnight later an injection of the ordinary virulent, unattenuated bacilli produced no bad results. The animal had been rendered immune by a gradual process of cell-education, which was made possible by the discovery of a method of attenuating the bacilli by means of heat. This method is applicable also to cattle and horses, and has now been in use for many years, having enormously reduced the mortality from anthrax.



THE MICROBES OF ERYSIPELAS

But there is a more interesting and significant way in which the virulence of microbes can be attenuated. Just as growth at something well above what is called its *optimum* temperature will weaken a microbe, so growth in the body of an animal of one species will commonly weaken or attenuate it, so far as animals of other species are concerned. The rule seems to be that the microbe adapts itself to the special conditions, and thus loses its suitability for other conditions. Thus Pasteur found that the parasite of swine-plague, when inoculated from rabbit to rabbit, increased in virulence for rabbits, but was attenuated for pigs Organisms which had been passed through a series of rabbits produced in the pig illness, but not death; and after this illness the pig remained immune to parasites of ordinary virulence for at least a year.

Pasteur's observations led to the discovery of the general principle that the virulence of a parasite for one species is diminished by its growth in another; and that thus vaccines may be obtained which

will induce a mild attack of illness in a member of the other species, *such as will protect that individual.* It is evident why we call such substances vaccines, for this process, utilized by Pasteur with certain parasites he identified, is the same as that invented before by Edward Jenner involving smallpox. Though Jenner was ignorant of the nature of the parasite causing smallpox, we now know it to be a virus that is very closely related to vaccinia virus, the causative agent of cowpox. Injection of smallpox virus into susceptible animals produces cowpox. But vaccinia virus obtained from lesions (sores) of cowpox-infected animals will not cause typical smallpox in man. Thus when we are vaccinated with vaccinia virus, we suffer from so mild a form of smallpox that it cannot even be called such; yet we are protected from that disease for years.

Lady Mary Wortley Montagu in 1718 introduced into England from the East — her husband was British ambassador at Constantinople — the practice of inoculation for smallpox. This meant actual inoculation from mild human cases. A number of deaths resulted, but the survivors were usually immune for life. Vaccination, properly carried out, causes no deaths, and it does not produce such long-maintained immunity. It acts by the method of inducing a mild attack by parasites attenuated by growth in another species.

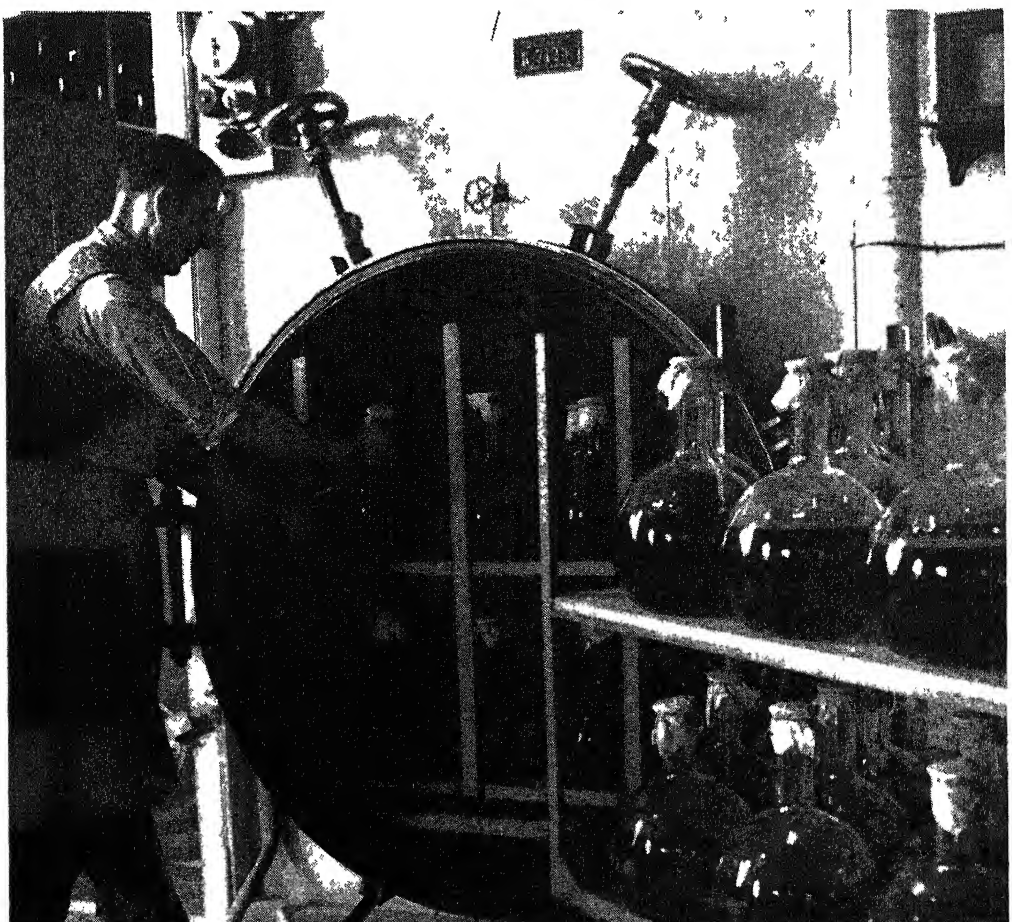
Just as the virulence of microbes can be attenuated in different ways, as we have just shown, so also it can be heightened. This is most easily done by the method of *passage* discovered by Pasteur, and illustrated in the case of hog cholera in rabbits. As the organism is passed on from one susceptible animal to another, it increases in virulence. This explains the fact, often observed, that epidemics increase in deadliness as they advance, for the later victims of the infection are attacked by parasites whose virulence is exalted by passage through the earlier patients. It has also been found that the virulence of a parasite is usually increased

United Press Photo

The Pasteur Institute in Paris, dedicated to the study and application of the science of bacteriology.

when some other parasite, or its poison, is injected in the host at the same time. The host's resistance is reduced, and the parasite can thus grow freely and increase in virulence. This fact is of extreme importance in all forms of tuberculosis, where septic conditions and neglect are liable to introduce further complications — largely, as we believe, because the virulence of the tubercle bacillus is enhanced under such conditions.

At least as famous as any other research of Pasteur's is his work upon hydrophobia, or rabies — an acute disease of mammals caused by a specific neurotropic (having affinity for nerve tissue) virus found in the saliva. After painstaking research on this disease Pasteur published his results in 1885. By following the principles already mentioned, he was able to provide himself with preparations containing the virus of hydrophobia in what may be called its normal strength, and in strengths of weakened and increased virulence. Since Pasteur had found that the virus is always most abundant in nervous tissues, he extracted the virus from the brain and spinal cord of various mammals that had been previously inoculated with this virus. With such preparations of varying strengths Pasteur sought to treat human beings who had been bitten by mad dogs, availing himself of the comparatively long period of incubation in man — forty days or longer.



Courtesy, Louis Pasteur Institute

Flasks containing culture media being placed in an autoclave. The autoclave sterilizes the flasks and media, after which the media are used as nutrition for bacteria or fungi in biological research.

The first case treated was that of a young shepherd boy who had been bitten by a dog; and his statue, representing him in the act of trying to defend himself from the animal, now stands outside the Pasteur Institute in Paris. This patient received a series of injections, from the spinal cords of rabbits, each successively being made from a cord of greater and greater virulence. Immunity was thus induced, and the dreadful symptoms of hydrophobia never appeared.

THE STATUARY GROUP OUTSIDE THE PASTEUR INSTITUTE IN PARIS, SHOWING THE ATTACK OF A DOG ON THE SHEPHERD BOY, JUPILLE, WHO WAS THE FIRST PATIENT FOR HYDROPHOBIA

It is, of course, a legitimate and necessary objection to the claims made for this method that the patient may not have been infected in the first place. Thus the Pasteur Institute does well to estimate its results only in terms of patients bitten by dogs proved to have had rabies by inoculation of healthy animals with parts of their nervous system. In the year Pasteur died 122 cases of this class were so treated, without a death. The ordinary mortality was 16 per cent of persons bitten, and this percentage would include a good many bitten by dogs not really mad. The results have steadily improved, and have been similarly obtained by Pasteur Institutes in many parts of the world — other parts of France, Italy, Russia and America. In Paris those who have carried on Pasteur's work have attained such perfection that the mortality, which was less than 5 per cent in the ten years preceding his death, has been reduced to practically nothing, with the sole exception of a few persons suffering from chronic alcoholism, in whom the process of immunization has been impossible of attainment.

Such, in very brief outline, is the life work of Louis Pasteur, but centuries must pass before all its fruits can be told. Of all physical benefactors of mankind, since the dawn of time, this man is supreme — the founder of bacteriology and the father of preventive medicine. "It is in the power of man," he said, "to make all parasitic diseases disappear from the earth." He was a devout Catholic, and was fond of saying "Tout est miracle", a remark worth recollecting by those who think that science has made all things plain because they have lately learned a fraction of what Pasteur discovered.

OUR COMMON BIRDS VI

The Beneficial and Destructive Hawks,
Soaring Eagles and Malignant Owls

THE BIRDS OF PREY

NATURE does not intend her children to lead easy lives. As soon as life becomes easy, progress ceases and decay sets in. There must be constant struggle and competition, and only the best and strongest must live to perpetuate their kind. She has little time to waste on the weak or the lazy; the sooner they are out of the way, the better for the rest. So nature has provided obstacles which every organism must surmount to reach maturity, and enemies to its adult life which require constant alertness and courage to escape. She provides every organism with a capacity for reproduction in proportion to the number of obstacles or enemies which it has to surmount, so that, though many may fall by the wayside, the most virile and progressive individuals will be left to continue the race. Wherever nature exists unmodified by man, we find a balance of these two great forces, that of reproduction and that of destruction, and all organisms maintain the same relative abundance year in and year out so long as the environment remains the same.

A single protozoon in a jar of water will in a few days cause the entire jar to appear milky with its thousands of offspring in order that at least one of its children may reach maturity and be carried to some other suitable environment. A soft-bodied, helpless plant louse reproduces at the rate of over ten sextillion a year for the same reason, and the oak tree showers its acorns on the ground every year that at least one may be carried to fertile ground, surmount the obstacles of browsing animals and defoliating insects and at last bear acorns of its own.

The protozoon, or the plant louse or the oak tree that finally reaches its maturity is the pick of thousands and has all the vitality of its parents and usually a little bit more. For it is thus that nature progresses and thus that the most complicated organisms have evolved from the lower and more simple.

And so we find whole groups of organisms intended by nature to cull out the weaker individuals of other species and thus assist the process of evolution. Among animals it is the carnivores, the tigers, the wolves, the bears, the weasels and their kin. Among birds it is the birds of prey, the hawks and the owls, that perform this necessary function of insuring the strength of the different species of birds.

Of course man does not feel the need of this method of maintaining the strength of his domestic fowls and rues the slightest pillaging of his poultry yard or game covers. Fortunately, there are few species that indulge freely in this thievery and the majority more than make up for it in their destruction of harmful rodents, for the food of hawks is composed even more of rodents than of birds.

There are nearly 500 different kinds of hawks, found in all parts of the world. Many species resemble each other very closely, others have diverged widely, but all can be recognized by their short hooked bills, their strong talons and the absence of the facial disc which characterizes the owls. Parrots, which are somewhat hawklike in appearance, have very thick bills and have two toes directed forward and two backward instead of three in front and one behind.

Hawks vary in size from the gigantic condor and the California vulture which measure over 12 feet from the tip to tip of the wings, to the pygmy falcons of India which are scarcely larger than a sparrow. The females are usually larger than the males, frequently exceeding them by several inches in length. Thus the male Cooper's hawk measures but a little over 15 inches in length while the female averages 19 inches.

Most species are inconspicuously marked with brown and gray, but some have quite striking patterns of blue and reddish brown. With some species, like the marsh hawk, the male and female are different, but usually the adults are colored alike and the immature are different. The adults tend to become very gray above and barred below while the immatures are brownish above and streaked rather than barred below. The color patterns of many species are so similar that it is much easier to distinguish them by their size or their shape than by their color. Thus the red-tailed, red-shouldered, broad-winged and rough-legged hawks all have large rounded wings and broad fanlike tails; the goshawk, Cooper's and sharp-shinned hawks have short rounded wings and narrow tails; the marsh hawk and the fish hawk have long narrow wings, and the falcons have very pointed wings. Each type is adapted for a particular feeding habit: the large-winged species circle high overhead on the watch for their prey and their wings and tails are therefore adapted for soaring; the short-winged hawks lie in wait for their prey in the shelter of the foliage and their wings are adapted to sudden bursts of speed from a stationary position; the long narrow-winged hawks beat back and forth over the meadow or the water and are on the wing for long periods of time, and their wings are adapted for sailing and long continued flights. The falcons pursue their prey and strike in full flight and, therefore, have pointed wings adapted for great speed.

All hawks are carnivorous, but the diet of some species consists largely of insects, snails, frogs, snakes, lizards or fish and some are scavengers and feed upon decaying animal matter. Their value in controlling small rodents can scarcely be overestimated.

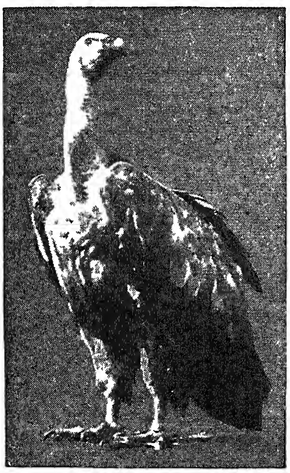
The eyesight of hawks is extremely keen and the power of focal adjustment is wonderful. From hundreds of feet overhead, they scan the ground and are able to see the tiniest mouse or lizard. In the instant required for them to drop from that height and pounce upon their victims, their eyes change from long to short focus, and the adjustment is so instantaneous that they follow their prey with clear vision. The eyes of hawks are smaller than those of the owls, for all the species are diurnal, although some species, like the rough-legged, are most active toward dusk, and the tropical laughing falcons can be heard long after dark. Hawks' eyes vary in color from yellow to ruby-red, some being gray and others brown. Young birds usually have different colored eyes from the adults, those of the Cooper's hawk, for example, changing from gray to yellow to bright red. In some species the eyes of the females are different from those of the male. Female marsh hawks, for example, have brown eyes while those of the males are yellow.

The voices of hawks, for the most part, are harsh, discordant screams, quite in keeping with their wild natures. The short-winged species, like the sharp-shinned and Cooper's hawks, that lie in wait for their prey, are usually silent, except on their nesting grounds, but the others call frequently as though to strike fear in their quarry.

There are four families of hawks found in North America, but, with the exception of the vultures, they may well be considered together. The family *Buteonidæ* includes the majority of hawks and are variously known as the broad-winged hawks, also called buzzards in Europe, kites, harriers, eagles, goshawks, etc. The family *Falconidæ* includes the falcons and the caracaras, the latter being degenerate falcons which have become largely vulturine in their habits. The family *Pandionidæ* includes only the fish hawks or ospreys, which differ from other hawks in that one toe is reversible so that a better fish gaff is formed by having two toes directed forward and two backward. The family of vultures, *Cathartidæ*, are degenerate hawks having naked heads and weak feet, and feed almost entirely upon carrion.

The vultures

There are nine species of the family *Cathartidæ*, confined entirely to the New World. The Old World vultures, although very similar in general appearance, are put in a different family. In North America there are but three species and one of these, the California vulture, is nearing extinction because of the poisoning of carcasses by rangers to kill wolves and coyotes. This is one of the largest and most majestic birds of flight in the world, some individuals measuring eleven feet from tip to tip of the wings. Every effort should be made to save the remnant that still may be found in remote portions of the California mountains. The other two species, the turkey and black vultures or "buzzards", as they are sometimes called, are very common in southern United States and occur as far north as New York and New England. The turkey vulture is the larger of the two and can be distinguished by its red head and longer wings and tail. The black vulture, having shorter wings, does not soar so continuously but flaps its wings more frequently while flying. The black vulture is more tropical and is seldom seen north of Virginia or Indiana. Both the turkey and black vultures have uniformly black plumage and naked heads and have the habit of soaring high on steady pinions, often rising far above the clouds without any apparent motion of the wings. Again in the same manner without a wing beat they will set their flight in one direction and disappear from sight. One of the most remarkable phenomena in connection with the vultures is the rapidity with which a flock will assemble about a dead animal, for in addition to scanning the ground, vultures keep keen watch on each other and when one indicates, by a change in its flight, that it has discovered something, all the others that have been watching it for miles around flock to the spot. Their vision is extraordinary, for the smallest dead snake or mouse does not escape detection by birds several hundred feet up in the air. It was at one time believed that their eyes were assisted by a very keen sense of smell, but it has been shown that if a strong smelling carcass is entirely concealed, the vultures do not discover it.



OLD WORLD VULTURE
Griffon Vulture

NEW WORLD VULTURE
Turkey Vulture

The value of vultures as scavengers was never questioned until recent years when it was supposed that they might assist in the spread of anthrax among cattle, and in some states the laws that had always given them protection were repealed. Few persons, however, bear the vultures any grudge and they will probably thrive even without the protection of the law. In most places they seem to recognize the good will of mankind and are not in the least timid, particularly the black vultures, which in the streets and markets of some southern cities form a regular part of the street-cleaning service. In parts of South America they are likewise employed to clean the hides of cattle of all flesh and fat. The hides are stretched on large frames and set out where the vultures are waiting, and the hand scraping, which is usually a tedious process, is found entirely unnecessary.

Except during the nesting season, vultures usually resort to a common roosting place toward which they can be seen sailing after sunset. Another common sight is to see them in early morning or after showers perched on the gables with spread wings drying their feathers.

Vultures lay their spotted eggs either on the ground under a log, in a hollow log or cave, or sometimes high up in a hollow tree. The young are covered with whitish down and are helpless for a long time. In fact, the South American condor, which is the largest of the family, is said to feed its young on the nesting ledge for nearly a year before they are able to soar like their parents. This is because their wings are so large and heavy that it takes great strength to manipulate them. Even the adult birds have difficulty in getting under way from level ground, particularly after gorging themselves upon carcasses. At such times they are often captured and before the importation of their plumes into the United States was prohibited, they were nearly exterminated over a good part of their range.

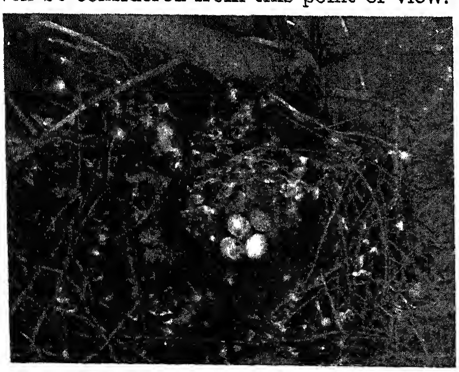
HEAD OF A CAPTIVE RED-TAILED HAWK
The so-called "hen hawk."

The true hawks

The majority of the true hawks belong to the family *Buteonidæ* and are variously known as kites, eagles, harriers, buzzards or hen hawks, goshawks and sparrow hawks or chicken hawks. The terms "buzzard" and "sparrow hawk" are both confusing because in America the former is used synonymously with vulture and the latter is applied to the smallest of the falcons. In Europe, however, the broad-winged, fan-tailed hawks are called buzzards and the short-winged, long-tailed hawks sparrow hawks.

Without reference to family divisions, there are four types of hawks according to the shape of their wings and tails and their corresponding food habits, and they may well be considered from this point of view.

The group of broad-winged, fan-tailed hawks includes the red-shouldered, red-tailed, broad-winged, Harris', Swainsons' rough-legged, and a few other hawks, and the bald and golden eagles. With their extended wings and spread tails, they circle high overhead as do the vultures, though, with the exception of the eagles, they are much smaller. In general, they live in wooded districts but do most of their hunting about open fields. They are all commonly spoken of as "hen hawks" and are supposed to be poultry thieves, but, in fact, the group feeds principally upon small rodents and the larger insects. The broad-winged and rough-legged hawks have practically a spotless record and the red-shouldered and red-tailed only rarely offend.



NEST AND EGGS OF RED-SHOULDERED HAWK

YOUNG RED-SHOULDERED HAWKS IN THEIR NEST

The photographs on this and succeeding pages of this chapter, except that indicated, are by A. A. Allen.

The members of this group of hawks are most usually seen soaring overhead and are best identified by the pattern of dark marking on their underparts. Thus the broad-winged hawk has the under surface of the wings pure white with the exception of the dark tip formed by the dark first primaries. The red-shouldered hawk has the under surface of the wings barred but with no distinct black patch; the red-tailed has a distinct crescentic black mark at the "wrist" which in the rough-legged hawk is very large and conspicuous.

The eagles are usually recognizable by their large size. The bald eagle was chosen as our national bird more because of its majestic appearance than because of its habits, for it feeds principally upon fish cast up by the waves or those which it steals from the osprey. Occasionally it takes crippled water-fowl. The adult birds have the white head and tail always illustrated, but the immatures have the head and tail brown like the back, and require several years to come into adult plumage. In fact, they are very similar to the golden eagle except in the feathering of the legs, the bald eagle having the lower tarsus bare while the golden eagle has the legs feathered all the way to the toes.

OUR NATIONAL BIRD
Adult bald eagle. It takes four years to develop the pure white head and tail

The golden eagle is very rare east of the Mississippi River, being most abundant in the mountainous parts of the West. It is a much more active bird than the bald eagle and preys upon rabbits, grouse, young lambs and fawns. The stories told about its carrying off young children are highly improbable since it has been shown that the greatest weight it can carry is six pounds. Like the bald eagle, it sometimes builds a bulky nest of sticks in the top of a tall tree, but more often it nests on ledges of inaccessible cliffs. In fact, all of these broad-winged hawks build very similar nests of sticks and lay similar spotted eggs.

The short-winged hawks include the sharp-shinned, Cooper's and goshawks. They seldom soar and when they do, it is in very narrow circles. Usually the habit of these hawks is to choose some inconspicuous perch and remain perfectly quiet until the disturbance which its arrival caused among the birds subsides. Then when the birds have forgotten its presence it dashes from its perch, usually with successful aim, but sometimes it misses and, still determined, may follow the victim on foot through the brush. Again, flying low through the woods or open country it will make a sudden dash into a flock of birds without any preliminary waiting, and at such times it is very bold and may strike birds within a few feet of one. These hawks

IMMATURE BALD EAGLES (CAPTIVE BIRDS)

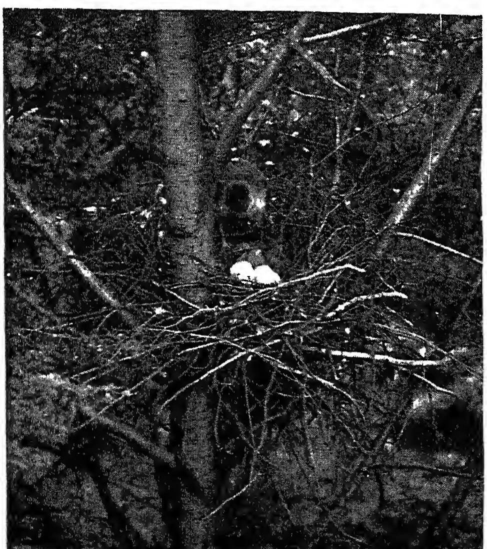
SPARROW HAWK AT ITS NESTING HOLE

YOUNG SPARROW HAWKS, ONE IN AN ATTITUDE OF DEFENSE

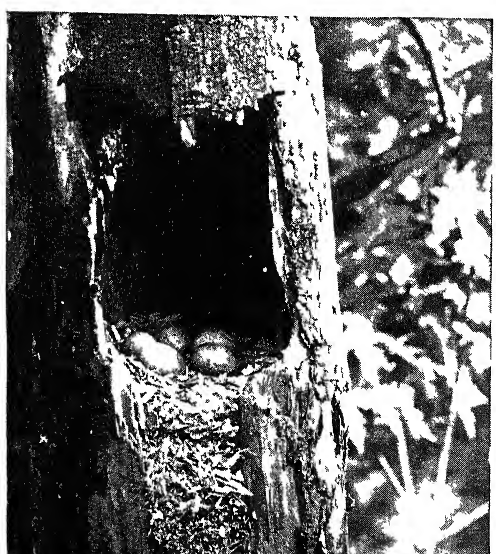
YOUNG SPARROW HAWK WAITING FOR DINNER

have been known even to pounce upon game birds that have just been shot before the surprised hunter has a chance to pick them up. During a recent summer, on two occasions, a sharp-shinned hawk attacked birds within twenty feet of the writer, and another time flew into an open window of the house, after making an unsuccessful dash at some birds at the feeding station.

These three hawks are the great bird destroyers which have brought the whole family into disrepute by their thefts in the poultry yard. The sharp-shinned hawk, because of its small size, usually confines its attention to the young chickens, but the Cooper's hawk may attack anything up to full-grown hens. The goshawk, which is a more northern species, coming southward into the northern United States in winter is the most destructive of all, and when it comes in big flights, as it does about every ten years, when the rabbit supply in the north fails, it is a great menace. The adult goshawk differs from the other two species in the color of its underparts, these being gray, penciled with narrow black lines The adults of all three species are dark slaty gray above and the Cooper's and sharp-shinned hawks have the underparts barred with rusty brown. The immature birds of



COOPER'S HAWK AT ITS NEST IN A TALL HEMLOCK



NEST OF A SPARROW HAWK IN A CAVITY IN A DEAD TREE

In the right-hand picture the side of the tree has been removed to show the eggs. The natural entrance was above and on the opposite side of the tree

all three species are brown above and white below, streaked with brown. The females are so much larger than the males that a female sharp-shinned is nearly as large as a male Cooper's so that the only safe way to distinguish the two species is by the shape of the tail, which is square in the sharp-shinned and rounded in the Cooper's hawk.

The falcons are perhaps the most striking and interesting of all the hawks. Although not of the large size, they are the most powerful and, with the exception of the sparrow hawk, strike their victims in full flight. The gyrfalcons, of the Far North, are the largest, measuring two feet in length; the duck hawk or peregrine falcon is next and the pigeon hawk and the sparrow hawk are the smallest. It was, preeminently, members of this family that were used in the day of falconry. The taming and training of hawks for sport was quite universal in Europe by the end of the ninth century, although it had been practised in China as early as 400 B C. The name "falcon" was ordinarily applied to the females, the smaller males being called "tiercels". In the 16th century, falconry had become so universal that everyone who could afford to do so kept a hawk, and the rank of the owner, we are told, was indicated by the species which he kept. Thus, a king kept a gyrfalcon, a prince the falcon gentle, an earl the peregrine falcon, a lady the merlin, a young squire the hobby. A yeoman carried a goshawk, a priest a sparrow hawk, and a knave or a servant a kestrel.

The gyrfalcons are northern in their distribution and must have been brought down from the Scandinavian mountains to England or the Continent. The European species is lighter and bluer than the American. The peregrine is almost identical with our duck hawk, the merlin with our pigeon hawk. The hobby has relatively longer wings than the other falcons and has no representatives in North America. The European goshawk has a more distinctly barred breast and the European sparrow hawk corresponds to our sharp-shinned hawk, while the kestrel is very similar to the North American sparrow hawk.

Falcons nest on cliffs or in trees but seldom build nests of their own more than enough to keep the eggs from rolling. The eggs are laid either on the bare ground, in cavities of trees or in the deserted nests of crows or other hawks, and are usually so spotted as to appear uniformly brownish.

Francis Harper—Fish and Wildlife Service

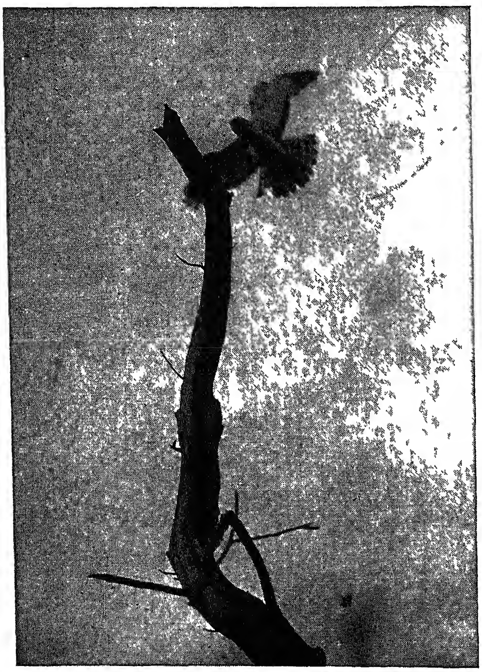
IMMATURE DUCK HAWK IN A DEAD HEMLOCK

YOUNG DUCK HAWKS ON NESTING LEDGE

The nesting ledge that is shown in the right-hand picture was about halfway up a fifty-foot cliff, rising from a river.

The hawks having relatively the longest and narrowest wings are the kites, the marsh hawks and the fish hawks, the last belonging to a separate family, *Pandionidæ*, and having quite different habits. In fact, about the only thing in common between the three is that they all remain on the wing for long periods at a time and have developed the type of wing which seems best adapted to gliding.

The kites are the lightest and most graceful of all the hawks, being almost swallow-like in their flight. Particularly is this true of the swallow-tailed kite of southern United States and tropical America, a strikingly marked white and black bird nearly two feet in length, whose swallow-like appearance is augmented by its deeply forked tail. The most beautiful and graceful sight that has ever been the writer's good fortune to behold was that of a troop of these birds skimming the water like a band of swallows, darting after one another in playful sport, rising abruptly hundreds of feet without apparent effort, diving, sailing, reversing, absolute masters of the air.



MARSH HAWK

About to alight on a stub overlooking the marsh and its nest.

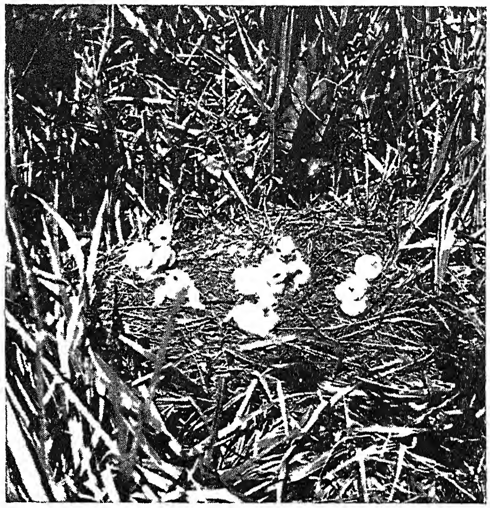
The marsh hawk is quite a different looking bird, though light of body and long of wing. It is seldom found far from the marshes, except during its migrations, although it does a great deal of feeding about open fields where mice are abundant. Occasionally it takes young ducklings or marsh birds, but most of its food consists of mice, frogs, snakes, etc. It can easily be distinguished by a white patch above the tail.

The marsh hawk nests on the ground, usually in the marshes but sometimes by stumps in upland pastures, and lays from five to seven pure white eggs. It seldom perches in trees, preferring some low perch on a fence post or on the ground. Occasionally, however, near the nest, it selects some high stub or dead tree from which it can keep a lookout. During the mating season the male performs curious evolutions in the air, sometimes turning somersaults from a considerable height toward the ground or again "looping the loop" on an angular course across the marsh.

The fish hawk or osprey is most abundant along the sea-coast but is found inland about most large bodies of water from the tropics to the Arctic Circle. With slight variations it is found all over the world Unlike other hawks, it sometimes nests in small colonies, especially where food is abundant, and where protection is afforded Thus on Gardiner's Island, L. I., there are about 200 of these birds nesting. It builds an enormous nest of sticks, usually on the top of a broken tree, although where protection is given them, as on Gardiner's Island, they sometimes descend to the ground.

Fish hawks are sometimes confused with bald eagles because of their great wing expanse and the large white areas on the head. Unlike the eagles, however, their underparts are white and their tails dark. They feed entirely upon fish which they locate near the surface of the water while hovering overhead and secure by plunging, often from considerable heights, and catching them with their talons The fish taken often weigh several pounds, and there is a record of a hawk that pounced upon a fish too large for it to lift, and being unable to release its talons, it was carried beneath and drowned.

A MALE MARSH HAWK AT ITS NEST AMONG THE CAT-TAILS



YOUNG MARSH HAWKS JUST HATCHED THIS VERY DAY

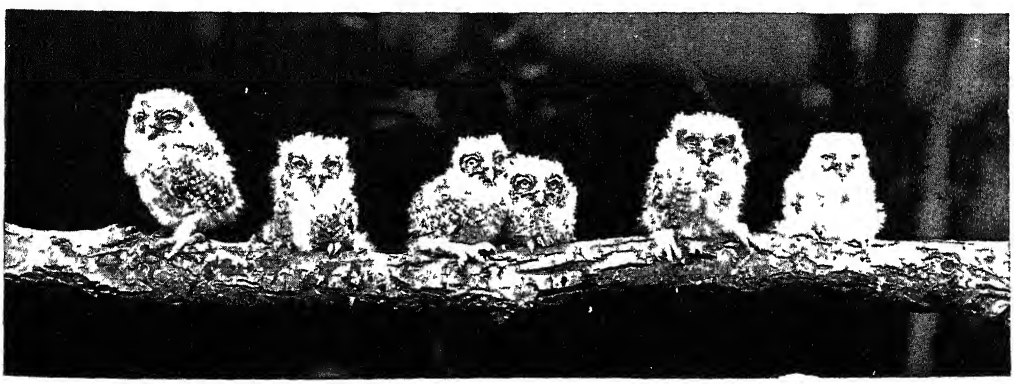
As before stated, the toes are placed two in front and two behind and the soles, moreover, are armed with sharp spicules for cutting through the slime and assisting in holding the slippery, squirming prey. The fish is carried lengthwise, usually to some high perch where it can be devoured. Fish hawks are sometimes quite destructive to spawning pike and pickerel but ordinarily the surface feeding fish which it catches are of little value.

Taking the hawks as a whole they are a much maligned group, as they are much more beneficial than destructive. The whole family is usually made to pay for the sins of a few, so much so, in fact, that even today, when most people are enlightened as to their value, we still hear a cry for bounties to be placed on their heads

No greater mistake could be made than to start a wholesale destruction of the birds of prey There are undoubtedly areas of extensive poultry or game production where hawks are too numerous and should be thinned out, but take it the country over, they are as necessary as any group of birds.

The owls

There is something irresistible about an owl. The killing of one creates an excitement like the catching of a horse thief or the hanging of a criminal, and even the sight of a dead one draws a crowd. Never is an owl allowed to die a peaceful death, or, once dead, to return to dust in the natural way. It must be stuffed and posed on a root and two great glass eyes set in its forehead, to " ornament " some shop or home.



YOUNG SCREECH OWLS

For some people a morbid charm seems to attach to the bird, because it hides during the day and comes out at night when crimes are perpetrated. The call of an owl is a sign of approaching death, and one must be quick to turn his pockets inside out in order to save his life or that of some one dear to him This and many other superstitions cling to the poor innocuous bird that sometimes approaches our dwellings to rid the garden of mice and rats

There are over 300 species and sub-species of owls in the world of which only nine are found in North America, but some species occur everywhere from the Arctic to the Antarctic with the exception of a few islands. Some species, notably the short-eared owl, are nearly cosmopolitan in their distribution, but the majority, if not local, show such range of variation in different localities as to be separately named. Thus the great horned owls in North America are divided into eight different races and the screech owls into nine.

In size owls vary from the elf owl of our Southwest, which is not much larger than a sparrow, or about 6 inches long, to the great gray owl that measures 27 inches in length and fully 5 feet from tip to tip.

In color owls are very much alike and also in form so that no one has any difficulty in recognizing owls, as such, at sight. The predominating colors are browns and grays though some species are distinctly yellowish, others reddish brown, and the snowy owl of the Far North largely white. The reason for their similarity in color doubtless lies in the similarity of their habits. Hiding during the day in hollow trees or close up against the trunk, the more they resemble the bark or dead wood, the less likely are they to be disturbed. So we find in the woodland owls, which group includes the largest number of species, that they are mottled, streaked and barred with various shades of brown and gray. To add further to the camouflage, the heads of a number of species are adorned with tufts of feathers called horns or ears, which give the head a jagged contour and render its protective coloration the more effective. The short-eared owls that live in the marshes are yellow and more striped like the dead vegetation, the burrowing owls are rather sandy, like the soil, and the snowy owls, belonging to the frozen north, are much whiter than the average.

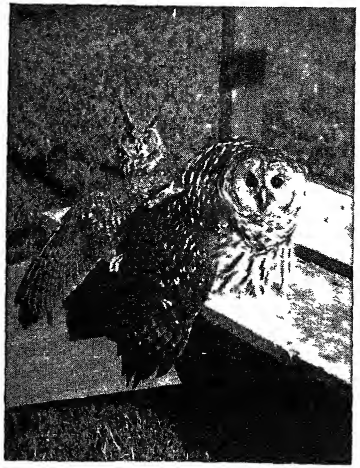
YOUNG SCREECH OWLS IN THEIR NESTING CAVITY

OWLS CAMOUFLAGING THEMSELVES
Screech owl mimicking a broken piece of bark.

PROTECTIVE COLORATION OF SCREECH OWL ON HEMLOCK

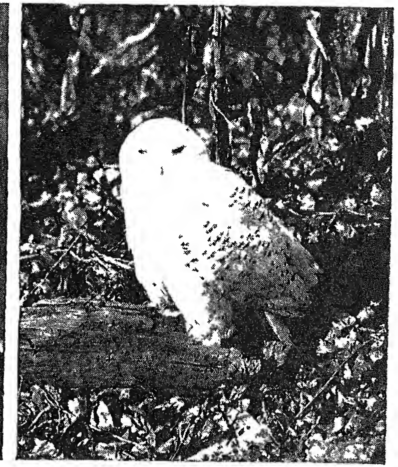
The color is but one of the many ways in which owls are alike. All are carnivorous and have sharp talons and strongly hooked bills. In this respect they are very similar to the hawks. Indeed, until recent years, a close relationship between the two groups was thought to exist, but it is now believed by most ornithologists that the similarity has been brought about by like feeding habits and that they are in reality quite widely separated groups, the owls being more closely related to the night hawks and whip-poor-wills. Aside from numerous anatomical differences, the owls are unlike the hawks in having their eyes set immovably in their sockets and at the front of the skull so that both are directed forward. For this reason, an owl has to turn its head in the direction in which it wishes to look. Owls' eyes are unusually large so as to admit as much light as possible for night work.

SOME FEATHERED SPECIMENS OF WISDOM PERSONIFIED



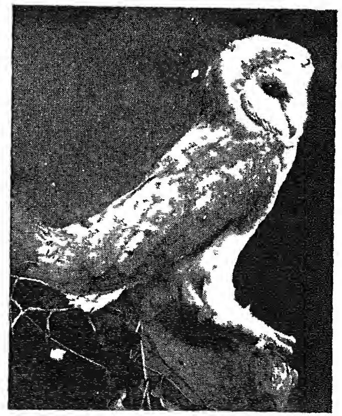
BARRED AND LONG-EARED OWLS

YOUNG LONG-EARED OWLS TRYING TO INTIMIDATE THE PHOTOGRAPHER

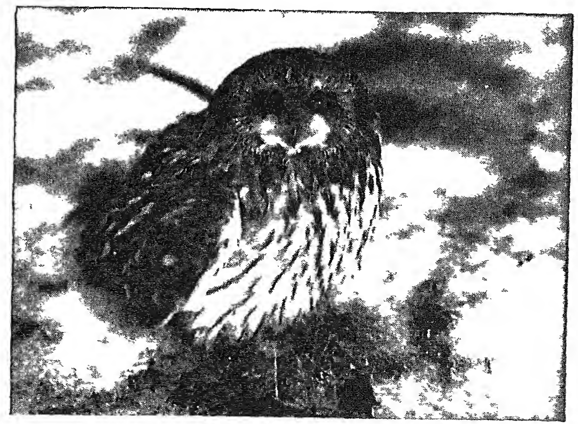


SNOWY OWL (CAPTIVE BIRD)

ACADIAN OR SAW WHET OWL (CAPTIVE BIRD)



BARN OWL



SHORT-EARED OWL (CAPTIVE BIRD)

The upper left-hand photograph was taken by D. Gordon, the central lower by C. Reid, the others by A A Allen.

It is commonly believed that owls cannot see during the day. On the contrary, they can see very well, for the iris can be drawn very close until scarcely more light enters than would with the normal aperture at dusk. The belief probably originated from the tameness or stupidity of some species which permit themselves to be captured during the day. On the other hand, certain species, like the hawk owl and snowy owl, regularly hunt by day and other species, like the short-eared and great-horned owls, hunt on dark days when they have young to feed.

Owls are not dependent upon their eyes solely for hunting or escaping enemies, for their hearing is extremely acute. The discs of stiff radiating feathers about the eyes, that give owls their somewhat human expression, are for the purpose of protecting the opening of the ear. The tufts of feathers that adorn the heads of many species, and are sometimes called "ears", have nothing to do with true ears. In most birds the ears open through small apertures, covered and protected by somewhat stiffened, modified feathers, below and behind the eye. No external ear is present. With the owls, however, although the canal leading to the internal ear is not relatively much larger, there is a true external ear in the form of a fold of skin and an underlying groove which extends from above the eye, around the side of the facial disc to below the bill. The facial disc protects the front edge of the ear and several rows of somewhat curled feathers the rear edge, but so closely appressed are they normally, that one might never suspect the presence of large ears. It is probable that hearing plays a very important part in the owls' pursuit of prey.

Another peculiarity of the owls, in which they differ from all hawks except the osprey, is that their toes are normally placed so that there are two in front and two behind. The outer toe, however, is opposable and can be brought around to the front. In the majority of species, the feathers extend down the legs and toes to the talons.

The feathers of owls are extremely soft, even those of the wing, so that these birds make very little noise in flying. The Indian name for the owl, "hush wing", refers to this, and the silence of their flight is almost proverbial. This permits them to fly through the woods or low over the meadow without frightening the small rodents upon which they feed.

Since most small animals are nocturnal and most birds diurnal, the chief food of the owl is small mammals and the birds suffer relatively little. Extensive studies of the food of owls made by the United States Biological Survey have shown a very small percentage of birds or poultry in the food of any species, except the great-horned. They are, therefore, among the most beneficial birds that we have, for it is absolutely necessary that some check be placed upon small rodents.

Take the meadow mouse as an example. This little animal has from five to eight young in a litter and from three to six litters a year or from fifteen to fifty young annually. If the number of young each year were only fifteen and they should multiply unchecked, there would be at the end of five years, over 75,000 offspring from each pair. It is not necessary for each one of these small rodents to do much damage for the aggregate to be unbearable. The destruction which a normal number sometimes do to young fruit trees or to grain in the stack often amounts to thousands of dollars. Where unusual numbers assemble because of an abundant food supply or successful reproduction, the damage done is stupendous. In Australia, during the Great War, when it was necessary to store grain in the open or on wharves, it was so defiled by rats and mice that the loss amounted very quickly to thousands of dollars. It is difficult to estimate accurately losses caused in the United States by prairie dogs, ground squirrels, pocket gophers, jack rabbits, meadow mice and pine mice, though a figure of over 150 million dollars has been advanced. House rats and mice account for a loss to our food supply of over 189 million, not including loss by human disease transmitted by these pests. In these days when the maintenance and increase of the food supply is so important, the value of owls, the rodent-destroying machines, cannot be overemphasized.

It is not difficult to prove to one's satisfaction what the local owls are feeding upon. All owls have the habit of swallowing their quarry, unless it be very large, entire, fur, bones, feathers and all. If it is very large, it is torn into a few pieces and these swallowed. The stomach digests the flesh, rolls up the bones and fur into neat oval packets and these are then disgorged in the form of pellets. Anyone familiar with the places where owls roost knows of these pellets. An examination of them, as shown in the accompanying photograph, shows how large a percentage, if not the entire food, is composed of small rodents.

GREAT-HORNED OWL (CAPTIVE)
With a duck

GREAT-HORNED OWL'S NEST IN A TALL PINE

The wandering movements of some owls make them the more efficient protectors of our crops, for they move from place to place, seeking abundant food. Particularly is this true of the short-eared owl, for whenever meadow mice become unusually abundant in a locality, and threaten to become a great pest, a flight of these owls usually follows. They remain in that locality, nesting if need be, until the rodents once again become scarce, and then they move on to another region.

The common prejudice against owls is due largely to superstition and to the destruction that is occasionally wrought about the poultry yard by the great-horned species. This magnificent but dangerous bird carries off full-grown hens and has been known to nip the heads from full-grown turkeys. It sometimes kills for the mere joy of killing, destroying many fowls during a single night. On poultry and game farms it is a bird to be feared and persistently trapped, but in the woods, where rabbits and mice and weasels are plentiful, it is more beneficial than destructive.

Another large owl that is often confused with the great-horned owl under the common appellation of "hoot owl" is the barred owl. It is nearly as large as the great-horned but it does not have the "horns" on the head and has none of the yellow-brown in its plumage characteristic of the latter. The plumage is distinctly barred rather than mottled. The calls of both birds are hoots that can be heard for a half a mile or more. The ordinary call of the barred owl can be distinguished by its ending in a descending nasal inflection, thus:

Whoo-hoo-whoo who-whoo-to-whoo-ah

while the great-horned owl's cry would be written:

Whoo, hoo-hoo-hoo, whooo, whooo

Both species, however, have other calls that are given occasionally.

The snowy owl is somewhat larger than either of these owls and is uniformly white, lightly barred with brown. It spends the summer from central Mackenzie and Alaska northward, and in winter from the arctic shores southward, sometimes as far as northern United States or even rarely as far south as Texas and Louisiana. Its southern migrations depend largely upon the abundance of rabbits and lemmings in the North. When these fail, which is usually once in ten years, considerable numbers reach the United States.

The long-eared owl resembles the great-horned in having ear tufts, but it is much smaller and more slender and does not have the white throat patch. It is usually found in evergreen thickets during the day and, except during the nesting season, all the owls of the vicinity may resort to one such thicket to roost. Sometimes the roost is in a single thick cedar tree.

The short-eared owl is found only about grassy marshes or pastures. Like its long-eared relative, numbers of this species spend the day together, usually on the ground, on tussocks or fallen logs in tangled places, where they will allow one to approach very closely before flushing. They then rise silently and fly off a short distance to drop noiselessly back into the tall grasses.

The commonest owl of all is the little screech owl, not much larger than a robin but much heavier since but little of its length is given up to bill or tail. It is found even in the heart of large cities in hollows of trees or in crevices about buildings, for the mice upon which it feeds are everywhere. It is represented by one or another of its nine races in all parts of North America. In color it varies from grayish brown to brownish red, the different colors having no bearing upon age, sex or season This unusual phenomenon is known as "dimorphism" and has never been satisfactorily explained. Like the great-horned and long-eared owls, it has conspicuous ear tufts, but it is easily distinguished by its small size. When seen during the twilight when it starts on the night's hunting, the ear tufts are frequently laid so far back as to be indistinguishable and the head looks round as in the saw-whet owl. The note of the screech owl, very far from being a screech, is a low tremulous whistle, sometimes almost a wail.

The saw-whet or Acadian owl is the smallest of the owls found in eastern United States, being only 8 inches long. It is usually encountered during the day in evergreen thickets, thorn bushes or other thick places and frequently is so tame or sleeps so soundly as to allow itself to be taken in the hand.

In the plains region of the West and in southern Florida occurs the burrowing owl, a strange little round-headed bird with legs longer than most owls' because of its terrestrial habits. The western owl lives in the prairie dog towns, but the Florida owl digs its own burrow in the sandy soil.

The two smallest owls are the pygmy and elf owls of the Southwest. The former is a diurnal bird flying around even in the bright sun in its pursuit of insects. It measures $6\frac{1}{2}$ to $7\frac{1}{2}$ inches in length and is about an inch longer than the tiny elf owl. The latter spends its days in woodpecker holes, particularly those in the giant cactus, and, like other owls, comes out at night to feed.

Another diurnal owl and by far the most hawk-like of all the owls is the hawk owl. It is a gray and brown bird somewhat larger than the long-eared owl and without ear tufts. Its tail is conspicuously longer than in other owls, which adds to its hawk-like appearance. It inhabits northern North America and comes southward in winter rather erratically.

The second family of owls, *Aluconidæ*, are called the "barn owls". There are about 25 species and sub-species, found especially in the warmer parts of the world. All are similar in color and habits although they vary in size. They differ from the other owls in having long slender legs and nearly white underparts speckled with black. The back is a very light mixture of tan and gray. The facial disc is continuous all about the face, which together with the black eye gives them a curious half human expression, so much so, in fact, that local newspapers sometimes announce the capture of a strange bird, half bird and half monkey, and one of its common names is the monkey-faced owl.

There is but one species of barn owl found in North America, occurring from the Atlantic to the Pacific, occasionally as far north as New York and New England. It lives about deserted buildings, towers and cupolas and is a most efficient mouse-trap, catching from three to six or more mice every night.

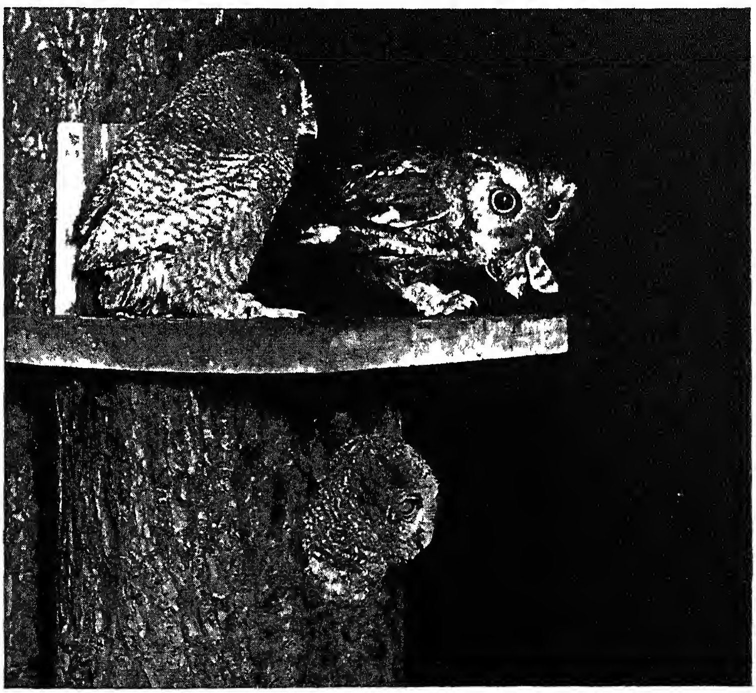
The majority of owls lay their eggs in cavities in trees without any pretense at a nest, but sometimes when these are not available, they utilize old nests of crows, hawks or even squirrels. The short-eared and snowy owls regularly lay their eggs in crude nests on the ground and the barn owls in buildings. All lay pure white, almost spherical eggs. The young are thickly covered with down when hatched and early learn the art of self-defense by dropping their wings, shaking out their feathers, as shown in the illustration of the young long-eared owls on page 3477, and then either clapping their bills or hissing.

When on the nest, the majority of owls sit very closely and allow themselves to be captured in the holes but others, like the great-horned, are usually very wary and will even desert the nest if molested. Owls usually begin to incubate as soon as the first egg is laid, sometimes both birds sitting on the nest side by side. Since the eggs are not laid regularly each day, as with most birds, the first eggs hatch much sooner than the last, and the young birds in a nest are often of very different ages.

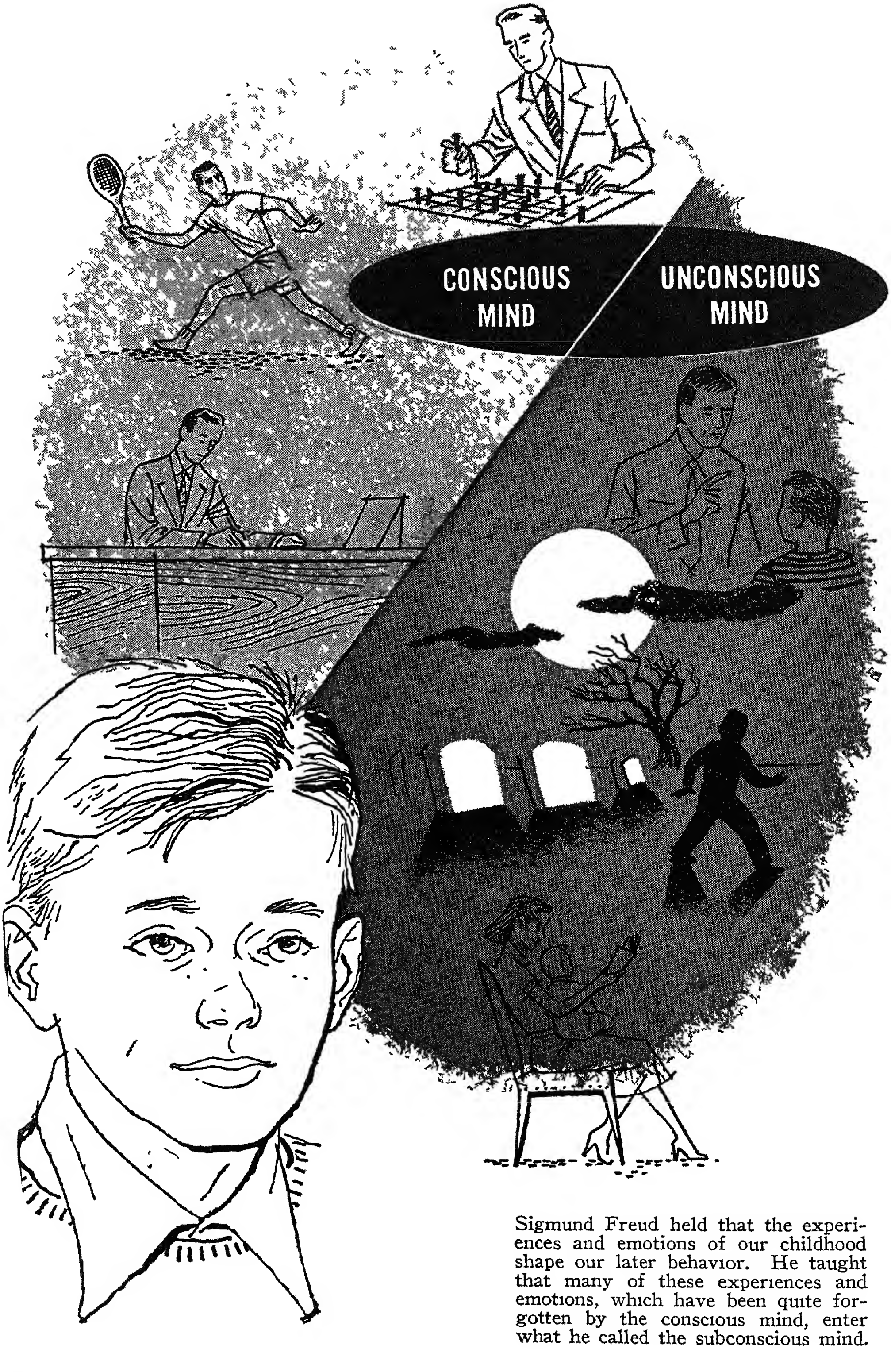
If a mother owl is captured with her young and confined in a cage with them, she will frequently devour them, even though she be well fed. They are quite bold in the defense of their young, particularly after dark, when if one ventures too close, he will often get eight holes in his scalp from the talons of the old bird.

Owls respond very readily to an imitation of their calls and will often come from considerable distances to investigate their supposed rivals.

Many interesting chapters of natural history might be written about owls and the average person would be willing to believe almost anything that might be told in them, but when all that is known has been said, the book of owl lore will be far from complete because their real life is just beginning when darkness obscures them.



FLASHLIGHT OF A SCREECH OWL
Returning to its young with a large moth.



Sigmund Freud held that the experiences and emotions of our childhood shape our later behavior. He taught that many of these experiences and emotions, which have been quite forgotten by the conscious mind, enter what he called the subconscious mind.

The Twentieth Century (1895-) IV

by JUSTUS SCHIFFERES

PROBING THE DEPTHS OF HUMAN PERSONALITY

"I DO not know what knowledge any of you may already have of psychoanalysis, either from reading or from hearsay. One thing at least I may presuppose that you know — namely, that psychoanalysis is a method of medical treatment for those suffering from nervous disorders."

Thus did the Austrian professor Sigmund Freud (1856–1939) begin his introductory lecture on psychoanalysis to an audience of medical students assembled in Vienna in the winter of 1914–15, a few months after the outbreak of World War I. Immediately after the war, the teachings of Freud — long suppressed by the Victorianism of earlier years — captured the interest and imagination of the world. The intelligentsia of the civilized nations eagerly adopted his ideas. Freudian words like "id," "ego," "libido" and "repression" were the prime stock in trade of American flappers and disillusioned young men — the so-called lost generation — of the 1920's. A new stream-of-consciousness literature, of which James Joyce's once-forbidden book, ULYSSES, is typical, came into being. Freudian thinking quickly invaded the fields of literature, history, biography, sociology, morals, aesthetics, education, anthropology and religion. Though still subject to some criticism, it has led to the development of a broader science of psychology.

G. Stanley Hall, a traditional psychologist and a former pupil of Wundt, "the father of experimental psychology," said: "It is precisely the topics that Wundt neglects that Freud makes his chief cornerstones — that is, the unconscious, the abnormal, sex and affectivity [the part of the mental life that has to do with emotion] . . . Psychologists of the normal have hitherto been too little disposed to recognize the precious contributions to psychology made by the cruel experiments of nature in mental diseases."

More successfully than anyone before him, Freud explored the "dark continent" of the human mind — especially the "unknown land" of the subconsciousness mind. More than any other man in the twentieth century, he made psychology a true and useful science. Where others had guessed and imagined, Freud proved and demonstrated. A medical man whose first aim was to make sick people well, he let his patients talk and talk to him in what came to be called psychoanalytic interviews; in this way he came closer than anyone before him to laying bare the structure — the anatomy, if you will — of human personality. He helped men understand what motives impelled them to hate, to love and to act; what inner conflicts — battles carried out in the subterranean vaults of the subconscious mind — made men sick mentally, emotionally or physically. Freudian psychology, which is decidedly complex, considers each person as a complete and distinct individual. It may be unfair or misleading to make generalizations about Freud's ideas, and it is certainly a mistake to apply them to yourself or your friends. Never attempt to be an amateur psychoanalyst! Psychoanalysis, like many powerful drugs used in medical practice, is a two-edged sword. It can kill as well as heal.

The substance of Freudian psychology may be briefly summarized as follows:

The great Austrian psychoanalyst Sigmund Freud was one of the most influential thinkers of the twentieth century.

Childhood experiences have a great deal to do with determining the later behavior — the emotional sets and drives — of any person. Very important among these experiences are the child's relationships to and feelings about his mother and his father. He may worry about their loving him too little, or he may be smothered by their loving him too much. Very often he does not dare to give expression to his feelings; he may be afraid of a whipping from his father or a scolding from his mother. Instead, he pushes down, or represses, his feelings. However, they are not lost just because they are forgotten by the child's conscious mind; they go into what Freud called the subconscious mind. This is a great reservoir of forgotten feelings and thoughts once held in the conscious mind.

The subconscious mind is capable of putting thoughts together in new combinations. This capacity is the basis of all great creative thinking in the arts and sciences. But sometimes the thoughts in the subconscious mind are at war with one another; hates and loves are all entangled. These twisted thoughts sometimes emerge in dreams and in slips of the tongue. In the dreams symbols often appear of persons and objects once feared or loved. Thus, a boy who once hated his father may dream of kicking a policeman, who is a "father symbol." Sometimes the repressed thoughts and feelings get into such a tangle that they hurt the grown child — the adult — and he cannot tell exactly what he fears or hates. He knows only that he is uncomfortable, and he wants to escape from this discomfort. The symptoms of most forms of mental disease — from maniac violence to such mild compulsions as overeating or washing the hands many times a day — are usually attempts to escape from inner hurts and conflicts.

Everybody, it must be insisted, suffers a certain number of frustrations and conflicts in the process of growing up. It is only when the reactions to these conflicts are excessive that the person is sick and needs the help of the psychoanalyst or psy-

chiatrist. The psychoanalyst tries to help the patient to get to the core of his secret and suppressed fears. Freud himself offered the best criterion for analyzing mental or emotional illnesses — namely, "How far does the person remain capable of a sufficient degree of capacity for enjoyment and active achievement in life?" It is important to realize that psychoanalysis is only one of many kinds of treatment at the disposal of the psychiatrist.

The validity of Freudian psychology is now generally accepted, but it had to fight an uphill battle for almost half a century. In 1915, Freud said, "There are two tenets of psychoanalysis which offend the whole world and excite its resentment . . . (1) that mental processes are essentially unconscious and that those which are conscious are merely isolated acts and parts of the whole psychic entity [the whole mental life of the individual] . . . and (2) that impulses which can only be described as sexual play a peculiarly large part — never before sufficiently appreciated — in the causation of nervous [emotional] and mental disorders — nay, more, that these sexual impulses have contributed invaluably to the highest cultural, artistic and social achievements of the human mind."

How did Freud arrive at the method of psychoanalysis to lay bare the dark secrets of the human mind? He was born on May 6, 1856, in Moravia, in the southern part of Bohemia; like many of the bright boys in that neighborhood, he was sent to nearby Vienna to study medicine. He also studied at Paris and at Nancy, where he went especially to study the work of the French physician, Ambroise Liébault, who was successfully using hypnotism in the treatment of patients with hysteria.

Freud became Doctor of Medicine at the University of Vienna in 1881, was made a docent (instructor) a few years later, and finally a professor. In 1926, he received magnificent birthday honors on the occasion of his seventieth birthday. Learned societies from all over the world sent him congratulations; the keys of the city of Vienna, which he had made famous as a center of instruction and treatment in psychiatry, were placed in his hands. A decade later, the dark, unreasoning clouds of nazi madness began to settle over his country. In 1938, after receiving a huge ransom, the Nazis allowed Freud, then old and ailing, to "escape." He died in London in 1939.

In his AUTOBIOGRAPHY (1925), in words reminiscent of Newton, Freud said: "Looking back then, over the patchwork of my life's labors, I can say that I have made many beginnings and thrown out many suggestions. Something will come of them in the future, though I cannot myself tell whether it will be much or little."

In the early years of his career, Freud made a careful study of the anatomy and physiology of the central nervous system. When he opened an office for private practice as a neurologist, he found it crowded with people suffering from neuroses (emotional ailments) and he did not know how to attack these problems. He went to Paris, where Jean-Martin Charcot (1825–93), the French pioneer in psychiatry, was teaching. Freud watched Charcot, in his clinics, use hypnotism to treat patients whose limbs had become paralyzed through hysteria (later shown to be secret fears). Hypnotism was then held in contempt by scientists. It smacked of quackery, they felt; it was a trick used by music-hall artists to entertain a crowd.

The term "hypnotism" — putting a susceptible subject into a trance — had been introduced by the English surgeon James Braid in the middle of the nineteenth century. Hypnotism is an offshoot of mesmerism, the peculiar and erroneous theory that disease could be cured by drawing "malicious animal magnetism" out of the body. Mesmerism was introduced about 1760 by a young Austrian medical student, Franz Anton Mesmer, who came upon the idea after reading Paracelsus! Mesmer cut a wide swath in France with his system of mesmerism and, strangely enough, he even effected some cures. A French Royal Commission, which numbered Benjamin Franklin and Lavoisier among its members, was appointed to look into Mesmer's

antics The commission concluded that the "magnetism" employed in mesmeric treatment was essentially hokum, but that the patient's imagination sometimes helped him to get better. Though mesmerism was scientifically discredited, it hung on in popular fancy; in time it gave way to hypnotism.

Jean-Martin Charcot, the greatest neurologist of his day, made a serious study of hypnotism. He described three stages of the hypnotic state: (1) drowsiness, (2) rigidity and (3) somnambulism (sleepwalking). Charcot also studied the disease called hysteria and found, contrary to popular belief, that it was as common in men as in women. He came to the conclusion that hysterical men and women could be cured by means of hypnosis. Charcot made hypnotism respectable

When Freud came to study under Charcot in Paris in 1885, hypnotic cures of hysteria were effected almost daily in the great French doctor's clinic. One day, observing Charcot treat a young woman with a neurosis, Freud heard Charcot say, "Sex is always at the bottom of these troubles." The remark impressed him deeply, as the subsequent development of psychoanalysis showed.

Returning to medical practice in Vienna, Freud came in contact with an older physician, Josef Breuer (1842–1925), who told him of a strange case in his own practice Freud has described this famous case in his AUTOBIOGRAPHY in the following words: "The patient was a young girl of unusual education and gifts who had fallen ill while she was nursing her father, of whom she was devotedly fond. When Breuer took over the case, it presented a variegated picture of paralyses . . . and mental confusion. A chance observation showed her physician that she could be relieved of these clouded states of consciousness if she were induced to express in words the . . . fantasy by which she was at the moment dominated. From this discovery, Breuer arrived at a new method of treatment . . . It turned out that all her symptoms went back to . . . events that she had experienced while nursing her father."

In 1895 Freud and Breuer published their famous STUDIES IN HYSTERIA, based on this case and others.

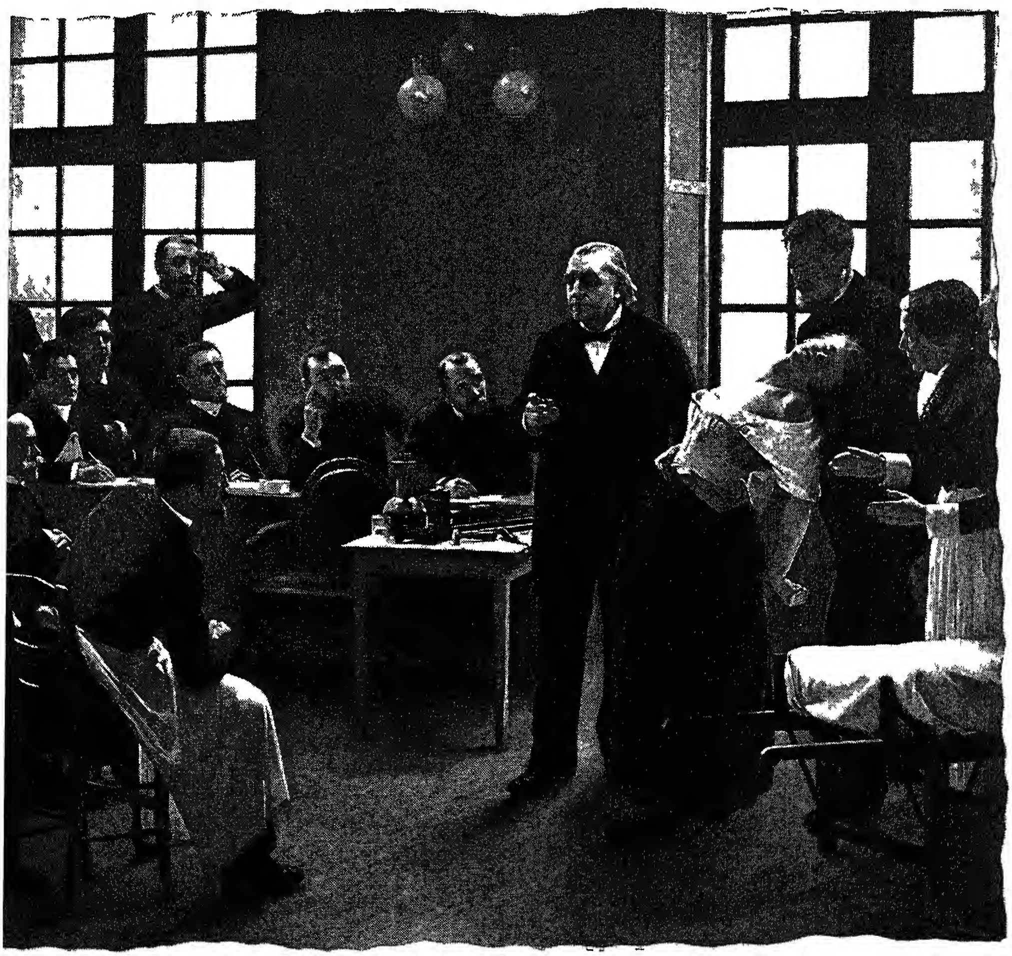
Freud eventually gave up hypnosis as part of his treatment and simply asked his patients to tell him everything — absolutely everything — that came into their minds. He interpreted and pieced together their disjointed remarks. Thus was psychoanalysis born; with it there came new insight into human personality.

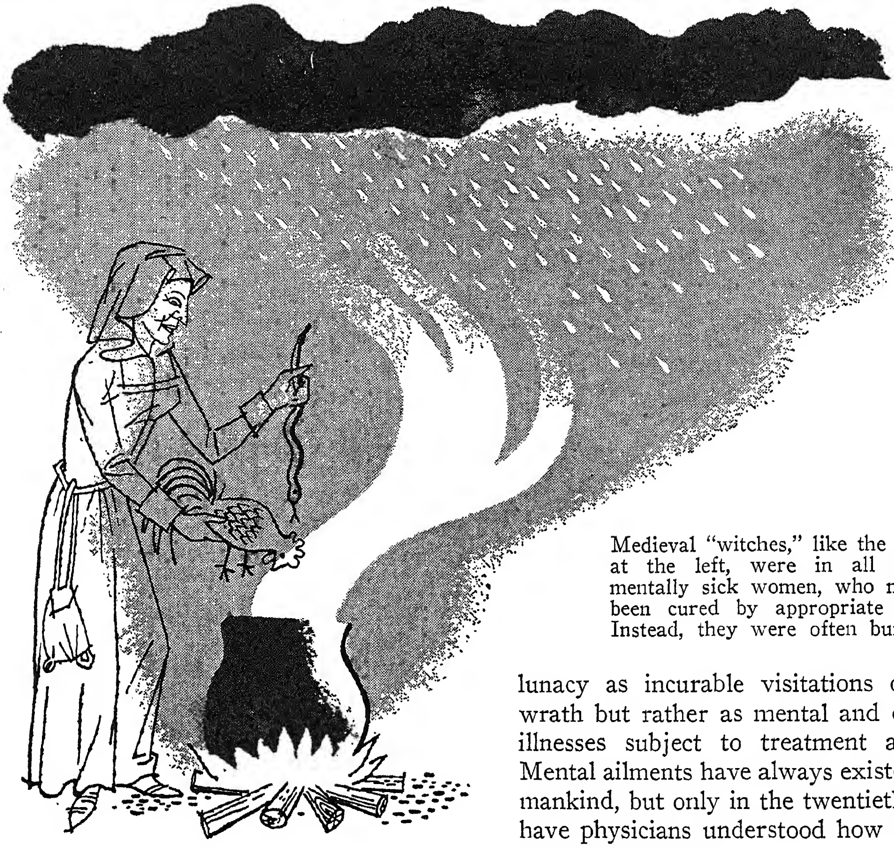
Words are the main tool of psychoanalysis and it is not surprising, therefore, that Freud himself was a voluminous writer. The titles of some of his major books give some idea of the wide range of topics that he covered: INTERPRETATION OF DREAMS (1900), PSYCHOPATHOLOGY OF EVERYDAY LIFE (1904), LEONARDO DA VINCI: A PSYCHOSEXUAL STUDY OF INFANTILE REMINISCENCE (1910), TOTEM AND TABOO (1912), GENERAL INTRODUCTION TO PSYCHOANALYSIS (1917), BEYOND THE PLEASURE PRINCIPLE (1920), AUTOBIOGRAPHY (1925), THE FUTURE OF AN ILLUSION (1927), CIVILIZATION AND ITS DISCONTENTS (1929), WHY WAR? (1933) and MOSES AND MONOTHEISM (1939).

Freud attracted many distinguished pupils, some of them later departed from their master's teachings and set up separate

Left Jean-Martin Charcot, distinguished French neurologist Below. scene in Charcot's clinic, here hysterical men and women were often cured by means of hypnotism

Culver Service





Medieval "witches," like the one shown at the left, were in all probability mentally sick women, who might have been cured by appropriate treatment. Instead, they were often burned alive.

schools. Alfred Adler's school of "individual psychology" stressed the importance of the inferiority complex. Carl G. Jung set up a school of analytical psychology in Zurich. Otto Rank originated the "birth trauma" theory, which held that man's emotional troubles are due to his first contact with an unfriendly world at birth. Karen Horney, a popular New York psychoanalyst, insisted that the neuroses of our time are caused by "contradictions in our culture." None of the later psychoanalysts and psychologists have denied the original insight of Freud. He not only showed how mental ills could be cured, but he also suggested that they might be prevented by paying greater attention to the psychological needs of the growing child. These are hopeful contributions to the society disturbed by his far-reaching ideas.

The treatment of mental disorders has been greatly influenced by Freud. It is, in part at least, because of his work that we no longer speak of madness or insanity or lunacy as incurable visitations of divine wrath but rather as mental and emotional illnesses subject to treatment and cure. Mental ailments have always existed among mankind, but only in the twentieth century have physicians understood how to handle them scientifically.

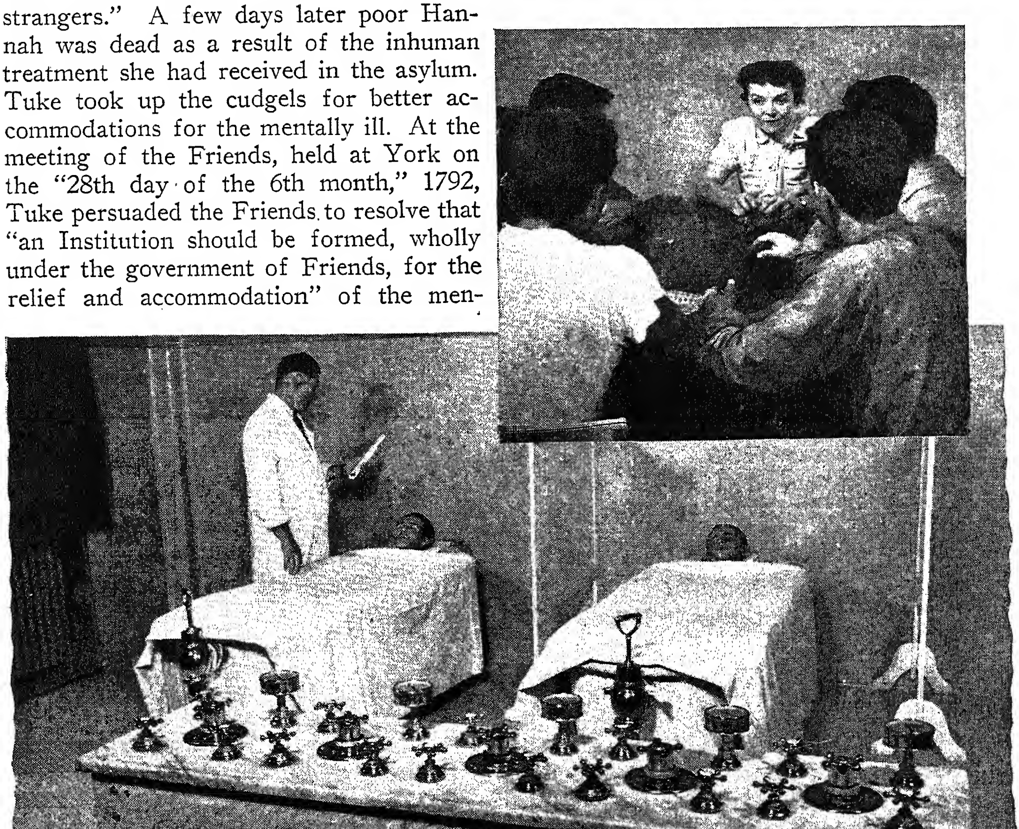
In ancient times and among savage tribes, emotionally disturbed people were supposed to be possessed by a demon; they were either worshiped or put to death. The ancient Greeks called epilepsy the "sacred disease"; but the great Hippocrates protested that it was no more sacred than any other disease and that it arose from natural — not supernatural — causes. We know now that many unfortunate women who were burned as witches in the Middle Ages and in later eras were really suffering from emotional ills that might have been cured by the appropriate treatment. The bold Dutch physician, Johann Wier (or Weyer), said as much in the sixteenth century, but his books were banned.

Treatment of the insane was for centuries, with certain exceptions, as cruel as it was ineffective. The sad lot of the mentally deranged in England in the eighteenth century, for example, was pictured by the great English artist William Hogarth. He has left us a series of unforgettable etch-

ings depicting the horrible sights in the London hospital of St. Mary of Bethlehem (often called Bedlam), where the unfortunate inmates were chained to walls and slept on filthy straw.

About the end of the eighteenth century, some efforts were made to improve these terrible conditions, both in England and in France. In the early 1790's, William Tuke, an enlightened English Quaker, was outraged when the tragic case of Hannah Mills was called to his attention. Hannah had been an inmate in a lunatic asylum in York. Her relatives had come a long distance to visit her; they were denied permission to see her on the grounds "that she was not in a suitable state to be seen by strangers." A few days later poor Hannah was dead as a result of the inhuman treatment she had received in the asylum. Tuke took up the cudgels for better accommodations for the mentally ill. At the meeting of the Friends, held at York on the "28th day of the 6th month," 1792, Tuke persuaded the Friends to resolve that "an Institution should be formed, wholly under the government of Friends, for the relief and accommodation" of the mentally ill, who "are truly objects of great sympathy and compassion." Two years later the York Retreat was founded by Tuke near York for persons requiring helpful and sympathetic treatment because they were "in a state of Lunacy or . . . deranged in mind (not idiots)."

Philippe Pinel (1745–1826) introduced humane treatment for the mentally ill in France. Appointed physician to Bicêtre, a grim and filthy hospital for the insane near Paris, he obtained permission from the National Assembly in 1798 to strike the chains off the mentally sick. The warder of the hospital was beside himself. "Citizen," he shouted at Pinel, "are you not crazy yourself to unchain these



National Film Board

Two techniques used in modern psychiatric treatment. Above: group therapy. A skilled leader guides a group of patients in the discussion of the problems that are bothering them. Below: a continuous bath. The patients lie in tubs of water kept at body temperature; this has a soothing effect upon them.

wild beasts?" But, as Pinel had expected, the "poor creatures" responded well to kindly treatment. He pointed out that intermittent or periodical insanity was the most common form. He showed that, time and again, a cure could be effected by setting the patient at liberty. Pinel's classification of mental disorders, though based on insufficient data, represented a real contribution to scientific psychiatry.

A crusade launched by a Massachusetts school teacher

In the United States the great nineteenth-century reformer in the hospital treatment of the mentally deranged was gentle Dorothea Lynde Dix (1802–87), a Massachusetts school teacher who became aroused by the shocking conditions she had discovered. She influenced the legislatures of twenty states to establish or to improve mental institutions. In a "memorial" to Congress she called attention to the fact that she personally had seen "more than 9,000 idiots, epileptics and insane in the United States, destitute of appropriate care and protection . . . bound with galling chains, bowed beneath fetters and lacerated with ropes." Miss Dix carried her crusade for reform of mental hospitals to Europe; she won an especially favorable hearing for her ideas in Scotland.

In the twentieth century, another movement for the reform of mental hospitals was spearheaded by Clifford W. Beers (born in 1876). A native of New Haven, a Yale graduate, young Beers found himself stricken with mental illness that almost drove him to suicide. After shocking treatment at several state hospitals and private sanatoriums in which he was confined, he recovered his sanity and determined to bring about reforms in the treatment of mental patients. He described his experiences in a remarkable book, first published in 1908 under the title A MIND THAT FOUND ITSELF. This work laid the foundation of the mental-hygiene movement. It brought into being the voluntary health agency known as The National Committee on Mental Hygiene (now the National Association for Mental Health), which works not only to improve hospital conditions but also to prevent mental illnesses through education and guidance clinics.

Scientific psychiatry made great strides in the twentieth century. Julius Wagner von Jauregg, of Vienna, for example, showed that the deranging effects of syphilis of the brain could be often successfully treated by malarial or other artificially induced fevers. In 1933, Manfred Sakel, a Viennese physician, discovered by accident that administration of insulin to patients suffering from split personalities (schizophrenia) would sometimes relieve them. Different kinds of shock treatment — insulin shock, Metrazol shock and electric shock — were quickly added to the psychiatrist's weapons against mental ills. During World War II, in the treatment of men suffering from combat fatigue, new methods of narcoanalysis (revealing one's troubles while under the influence of sedative drugs) and group psychotherapy were developed. Operations for the destruction or removal of parts of the brain (lobotomies) have also been worked out.

Twentieth-century contributors to psychiatry

Among the great contributors to psychiatric thought and practice in the twentieth century have been the Swiss psychiatrist Eugen Bleuler, Abraham A. Brill, who translated the works of Freud into English; Adolf Meyer, a Swiss-born teacher of psychiatry at The Johns Hopkins University; Smith Ely Jelliffe, a pioneer in psychosomatic medicine; and the brothers Menninger (Karl A. and William C.), whose clinic at Topeka, Kansas, is a pioneering center of psychiatric treatment, training and research.

It has been said (this is opinion and not fact!) that science has made the civilization of the twentieth century so complex that more and more mental and emotional disorders must be expected. If this is so, it is also true that twentieth-century psychiatry has provided the means of helping to cure and prevent such disorders.

SCIENCE THROUGH THE AGES is continued on page 3597.

TUNNELING THE EARTH

How, by Tunneling, Man Has Made New Avenues for Traffic and Pierced Nature's Most Stupendous Obstacles

MOUNTAIN, SEA AND CITY UNDERMINED

THE Egyptians, Chaldeans, Hindus, Aztecs, Greeks and Romans were all famous for their work underground, and the feats which they accomplished seem almost incredible when it is remembered that they had only the simplest of tools and were unaided by the rock drills, air compressors, dynamite, tunnel shields and a hundred other inventions at the modern engineer's command. Today works which surpass the wildest dreams of the ancients are accomplished as ordinary feats, all "in the day's work", receiving no more than passing mention.

Rushing trains bear their passengers under high mountains and beneath harbors and rivers; water supplies are brought to cities through tunnels miles in length, and the earth beneath our metropolitan centers is a veritable honeycomb of underground passages which carry traffic or serve as conduits for water, heat, gas, electricity and mails.

One of the oldest large tunnels in the world was built by the Romans under Monte Salviano for the drawing of surplus water from Lake Fucino, which had no natural outlet. It was 3½ miles in length, and was in places 400 feet below the surface. It was designed to have a width of 6 feet and a height of 10 feet, but when in 1862 it was opened after having been closed for centuries, it was found to be very irregular in its section. It is stated by Pliny that 30,000 men were employed for eleven years in its construction, most of the rock being removed in pails having a capacity of less than 2 cubic feet.

The longest railroad tunnel in the world is the Simplon, under the Alps, having a length of 12¼ miles. Next to this in length comes one at Schemnitz, Hungary, constructed to carry off the water from the mines. This is 10.27 miles long and holds the record for slow construction, having occupied 96 years in its building, from 1782 to 1878. Its section measured 9 feet 10 inches high and 5 feet 3 inches wide. Its total cost was about $5,000,000 or $92 per foot of length.

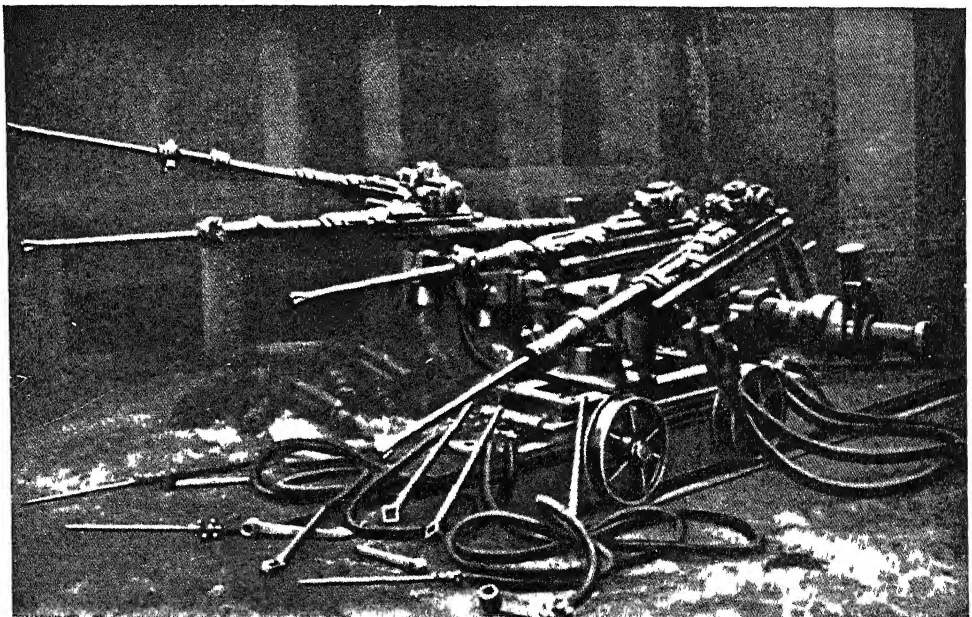
Tunnels like the Lake Fucino and the Schemnitz are very tedious in constructing and often dangerous, but they are simple compared with tunneling under high mountains or under harbors and rivers. In the former case, vertical shafts are generally sunk at intervals along the proposed line, and these provide not only means for removing excavated material ("muck"), but also for aligning the tunnel and ventilating it during construction and afterward. Ventilation in deep and long tunnels becomes a most important factor. Shafts cannot well be sunk in the case of high mountains or under-water work. Other methods must be followed which are accompanied by more or less hazard.

The great era of tunnel building began with the development of the steam railroad, and the ever increasing demands of transportation have been the incentive of the tunnel engineer. The construction of the early tunnels must have entailed difficulties and hardships beyond the present-day experiences. The men toiled with pick and hand-drill in dim candlelight surrounded by darkness and unprotected against cave-ins, hidden streams of water, heat and near-suffocation. No mechanical appliances were available for help, and ill-health and death were only too often the ultimate reward of the laborer.

For instance, in the construction of the great St. Gothard Tunnel under the Alps, the loss was appalling, totaling 800. To-day, tunneling is, comparatively speaking, a fairly safe occupation. This has been brought about by the invention of the tunneling shield and the use of air compressors to furnish fresh air to the workers and power to operate the large rock drills. The most imposing triumphs of man in rock tunneling have been won in the piercing of the Alps by four different tunnels, the Mont Cenis, the Arlberg, the St. Gothard and the Simplon. These are the names of the great passes under which the tunnels were driven. The borings in all four cases were made by use of rock drills and high-power explosives. The Mont Cenis, the first of the four, was also the first tunnel in which this method was employed. The drill was driven by compressed air carried from the power plant through lines of piping.

When solid rock is drilled, the whole face is seldom blasted out at once, but a narrow opening or "drift", as it is called, is opened up at the side or bottom of the "heading", and the loosening of the remainder is a comparatively easy task. Generally, borings through solid rock are left without further finish, no linings being required unless a smooth surface is desired, as in tunnels for conveying water.

The Mont Cenis Tunnel was completed in 1871 and is 7.5 miles long, passing under the highest point of the mountain at a depth of 5275 feet. The St. Gothard, opened in 1881, is 9.25 miles long. The Arlberg, 1883, is 6.5 miles in length, and the Simplon, opened in 1905, is 12.25 miles long. As stated elsewhere this is the longest railroad tunnel in the world, and its cost is placed at about $11,750,000. Its cost per foot, however (approximately $180), was only about one-half that of the Mont Cenis Tunnel, built thirty-four years earlier. Its average progress per day was also greater, being close to 27 feet, while that of the Mont Cenis was only 7.5 feet, and this notwithstanding the fact that the interruptions to the progress of the work were more serious than those which occurred in the Mont Cenis. All of which goes to show the rapid advance which was made in methods and machinery. The boring of the St. Gothard occupied nine and a quarter years of continuous labor, day and night, making the



From Lauchli's *Tunneling*, McGraw-Hill Book Co.

DRILL CARRIAGE USED IN A SWISS TUNNEL

progress about one mile per year. It gave nearly continuous employment to about 3500 men. Water power was developed at each end of the tunnel to drive air compressors. Fifteen hundred horse-power was thus obtained at the Goschenen end and eleven hundred at the Airolo end. Locomotives driven by compressed air were used in hauling away the excavated material. This tunnel cost about $235 per foot of length.

The Simplon Tunnel occupied seven years in construction. It comprises two separate tunnels, running parallel to each other, the second being a smaller one for ventilation. The main tunnel is 14 feet 9 inches wide at the rail level and 18 feet high at its center.

Exceptional difficulties were encountered in constructing these Alpine tunnels. The temperature increased as the tunnels penetrated deeper, and as the height of the mountains increased. In the St. Gothard, just before the headings met, it was as high as 93° F. This caused serious delays in the progress of the work. Men were not able to do so much. The ventilation also proved insufficient, and many men and horses were suffocated by the gases generated from the dynamite in blasting. It was estimated that the actual work done was lessened by one-half, a serious loss on the labor of three thousand men. Yet 4,476,000 cubic feet of air were being pumped into the heading daily. The ventilation in the St. Gothard, after the completion of the tunnel, is performed by nature alone. A current of air is set up by the difference in barometric pressure which exists at the two sides of the Alps.

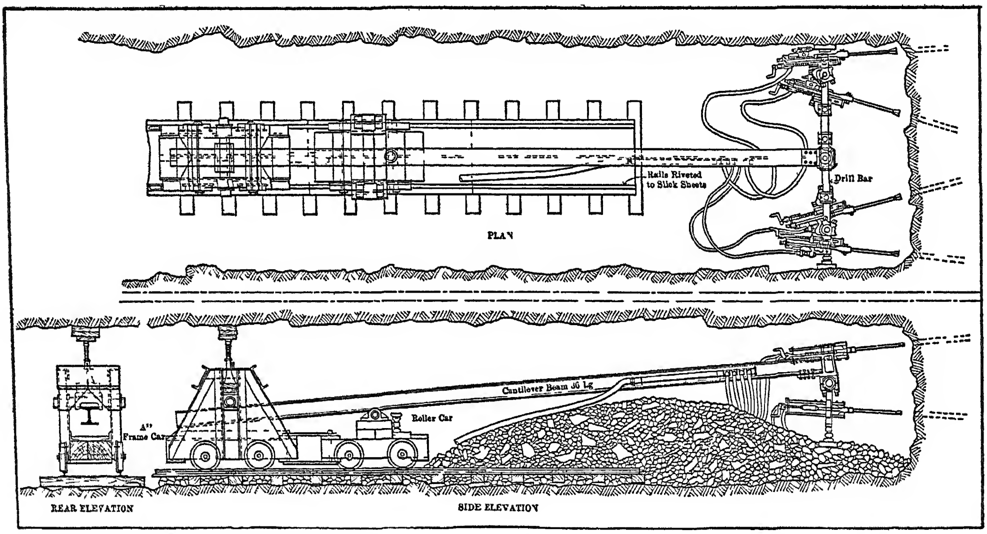
UNDERGROUND STREAMS OF WATER ENCOUNTERED IN THE SIMPLON TUNNEL

A very remarkable and unusual experience in the St. Gothard was the sinking of about a hundred yards in length of a completed portion of the tunnel. This was due to the strata there being composed of calcareous materials which swell and disintegrate with absorption of water. Ultimately the section was enlarged and thickly lined with granite masonry.

Another famous tunnel is that which was driven to carry the old Troy and Greenfield Railway (now a part of the Boston and Maine) under the Hoosac Mountains in western Massachusetts. It stands as the result of sixteen years of labor, having been begun in 1858 and finished in 1874. Its length is $4\frac{3}{4}$ miles and the cost of construction about $10,000 000. Although its construction if undertaken at the present time would entail no very great or difficult problems, it must be acknowledged that it was at that time a great engineering feat. It was driven through a mica schist of almost granite hardness, at first by the use of the hand drill and black powder, but later by the aid of machine rock drills and dynamite, both of which came into use about this time. The tunnel was contemporaneous in construction with the Mont Cenis, and many of the men employed were in fact brought to this country upon the completion of the latter tunnel. The delays and interruptions were many and numerous, but mostly due to failure of the early drilling machines and several changes in engineers and contractors. The work of removing the material and the alignment of the tunnel was facilitated by the sinking of vertical shafts from the

mountain top to the tunnel grade. These, also, furnished means for ventilation during construction. It was in connection with one of these tunnels that the worst accident during the work occurred. The central shaft had been sunk to a depth of 583 feet, or about half its final depth, when a fire broke out in the large house which had been built over the shaft's mouth, and used as a general storehouse and office. There were thirteen miners at work at the bottom of the shaft at the time, and an effort was made to rescue them by means of the hoisting bucket, but without success. The fire burned away the cable, dropping the heavy bucket, and this was followed shortly by the landing floor at the top of the shaft, upon which were piled three hundred hammers, drills and other steel tools. This awful shower of steel fell on the miners below, followed in a few moments by the roof timbers of the burning building. Months later when the shaft was finally cleared, the bodies of the thirteen miners were found.

Every large tunnel has its death toll, and in the Hoosac this numbered one hundred and ninety-five. Modern methods and safety devices have greatly reduced the loss of lives until now tunneling may be said to be a comparatively safe occupation.

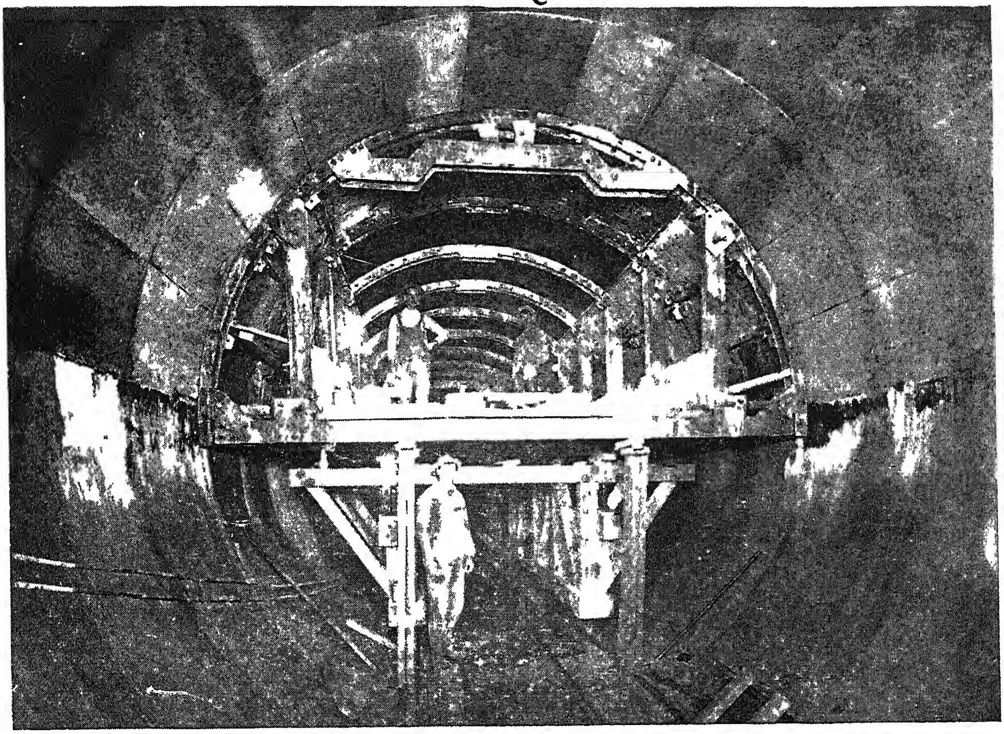


From Lauchli s *Tunneling*, McGraw-Hill Book Co

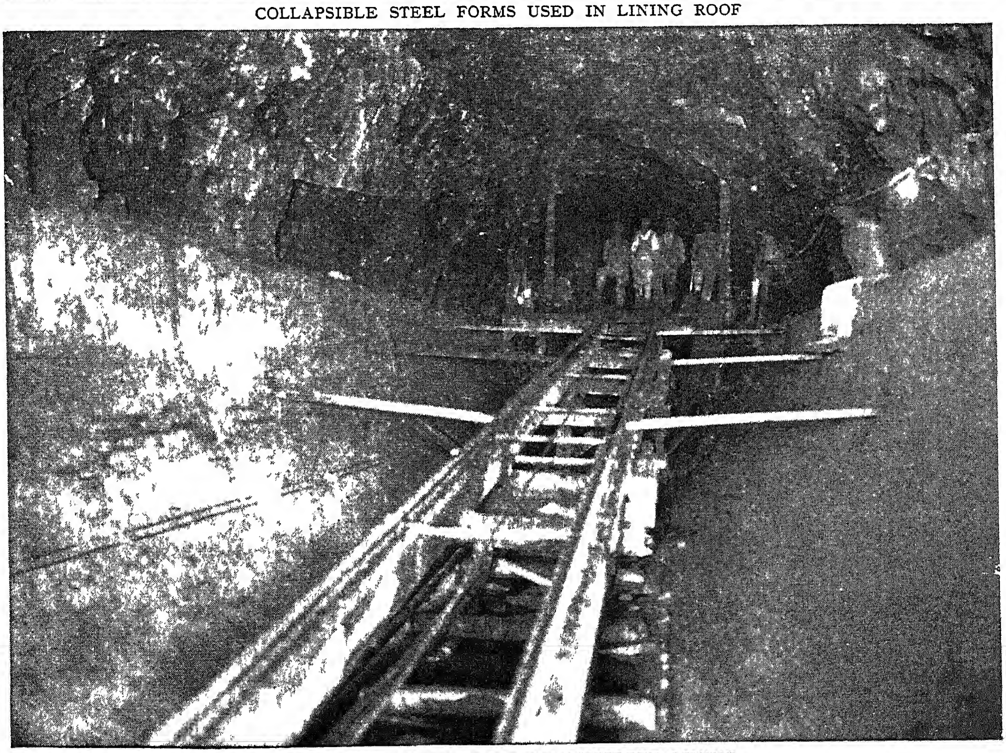
DRILL CARRIAGE USED IN MOUNT ROYAL TUNNEL

The greatest difficulty and danger in boring long tunnels is due to the uncertainty as to the character of the strata which will be encountered. Though, in general, geologists are able to determine the nature of the strata through which tunnels will have to pass, their information is not always reliable; and however many borings are made, they do not always reveal the presence of the faults which are subsequently discovered. The most dreaded of these consists of loose, sandy materials and water. Nearly all the disasters which have occurred in tunnel making have arisen from one or both of these sources. Borings could not have been taken in the Alps, but geologists stated very approximately the character of the strata which would be met. On the northern side of the St. Gothard Tunnel, 6000 feet of solid granite was excavated in the dry. But on the southern side, the discharge of water from the yielding and disintegrated rock was 4000 gallons per minute, the equivalent of thirty good fire-streams. Often the drilling-machine frames had to be laid in a torrential stream, twenty inches deep. The men worked incessantly in a tropical rain descending from the roof, while frequently solid jets as thick as a man's arm burst out from floor or wall.

IN THE CATSKILL AQUEDUCT TUNNEL



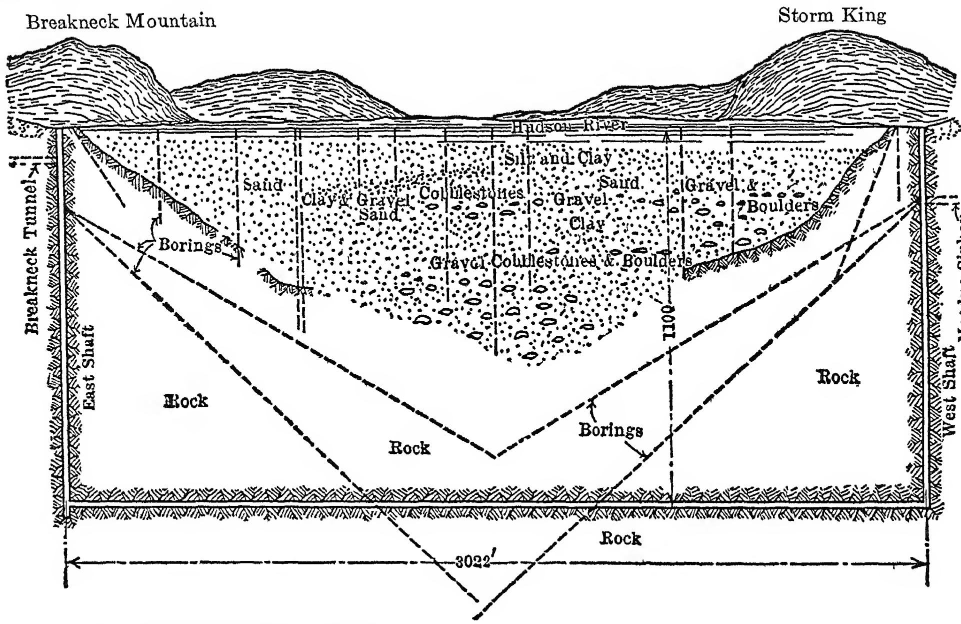
COLLAPSIBLE STEEL FORMS USED IN LINING ROOF



COMPLETED LOWER HALF OF CONCRETE LINING

To add to the difficulties, the workings were always at a high temperature which was increased by the blastings of dynamite so that 85° F. and over was recorded. The heat on the south was higher than on the north, due probably to the greater height of the mountains there. Almost worse than this is the inrush of water from hot springs, such as happened in the Simplon Tunnel. These would knock down the workmen and raise the air temperature so high that work became impossible. Cold water was then brought to mix with the hot water and lower the temperature so work could be resumed.

bridging, placing steel pipes on the river bed and tunneling, it was finally decided to adopt the latter method, locating the tunnel in the bed-rock which, in places, completely underlay the river. The project is interesting chiefly by reason of the extreme depth to which it was necessary to go and also because of the exploratory borings made before construction. The accompanying drawing shows these two features. It was necessary that solid rock be encountered throughout, not only to facilitate boring, but to prevent possible future injury to the tunnel by slipping or crushing. Borings were made at many



From Lauchli's *Tunneling*, McGraw-Hill Book Co.

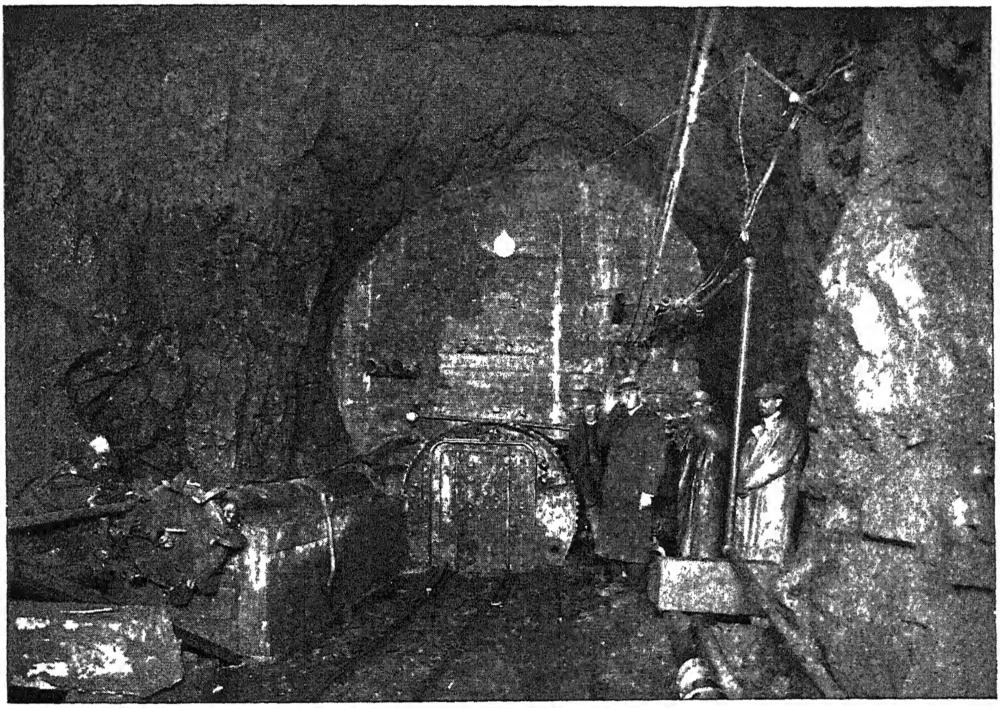
CATSKILL AQUEDUCT TUNNEL AT HUDSON RIVER CROSSING

In addition to the several hundred railroad tunnels in this country, there are a great many which have been built either for drainage purposes or to carry water supplies, and no article on tunnels would be complete without mention of the one finished in 1913 under the Hudson River at Storm King to carry the waters of the Catskill Aqueduct, described in the chapter "A City's Water Supply". To reach New York, the aqueduct had to be carried across the Hudson River, and, after comparative studies as to the advantages and disadvantages offered by

places along the proposed route, both on shore and in the channel to ascertain how far down it would be necessary to go to find such rock. The deepest of these borings were made with diamond-faced drills, and in the center of the river, where the water was about 130 feet deep, such a drill was sent to a depth of nearly 800 feet without showing positive evidences of solid rock. Inclined borings were then made from the two banks, and two sloping holes 1830 feet and 2050 feet long were driven from the east and west banks, respectively, at an angle of about 45° with

a horizontal, and they very nearly encountered each other, as may be seen in the diagram, at a depth of about 1650 feet below the surface. Two more holes about 1650 feet long were then driven at an angle of about 25° with a horizontal, intersecting each other at about 960 feet below the surface. From an examination of the borings, it was seen that the material was chiefly hard granite free from any serious seams or weak spots. One of the holes gave considerable trouble by discharging relatively large quantities of water, showing that at some point it was finding its way from the river down through the otherwise solid rock.

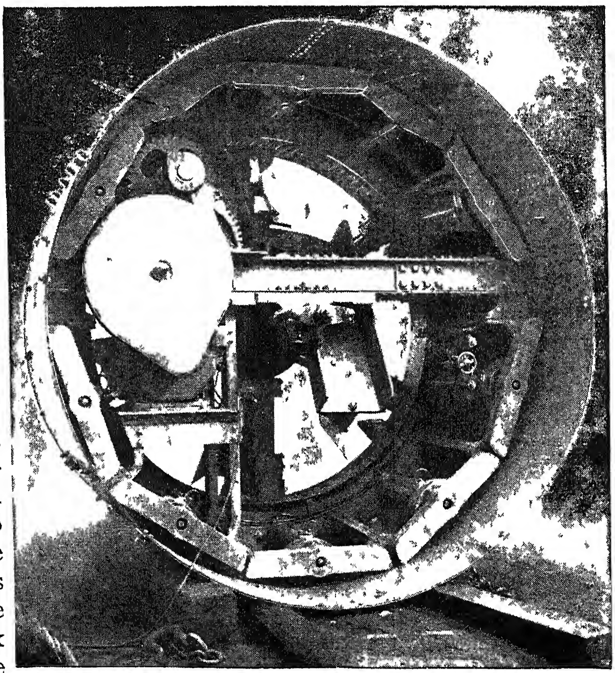
It was finally decided to locate the tunnel about 1100 feet below the river surface, and this was accomplished by first sinking, on either bank, vertical shafts to this depth and then opening up horizontal headings. The length of the tunnel itself is 3022 feet, the section being circular and 14 feet inside diameter. Both shafts and tunnel were finally lined with concrete not only to provide a smooth conduit for carrying water but also in order to prevent seepage from the river. At one point, the workmen were driven back by the inrush of water from a water-bearing stratum, and no progress could be made until an 18-foot wall of concrete had been placed across the tunnel heading and by means of pipes placed through it, liquid cement (grout) forced into the leaking seams under a pressure of from 400 to 900 pounds per square inch. When this grout had hardened, the removal of the concrete bulkhead showed that the inrush of water had been reduced to a slight dampness which showed itself on the tunnel roof.



CONCRETE BULKHEAD WITH LOCK, CATSKILL AQUEDUCT TUNNEL

Besides encountering this seam of water, there was an occasional "popping" of rock as the excavation proceeded. Fragments of the solid rock would suddenly shoot from the sides of the tunnel with terrific force, accompanied by a loud explosion, and it became necessary to protect the workmen with steel shields placed around the sides of the tunnel. This popping was explained by geologists as due to the relieving of great pressures which had previously existed in the rock.

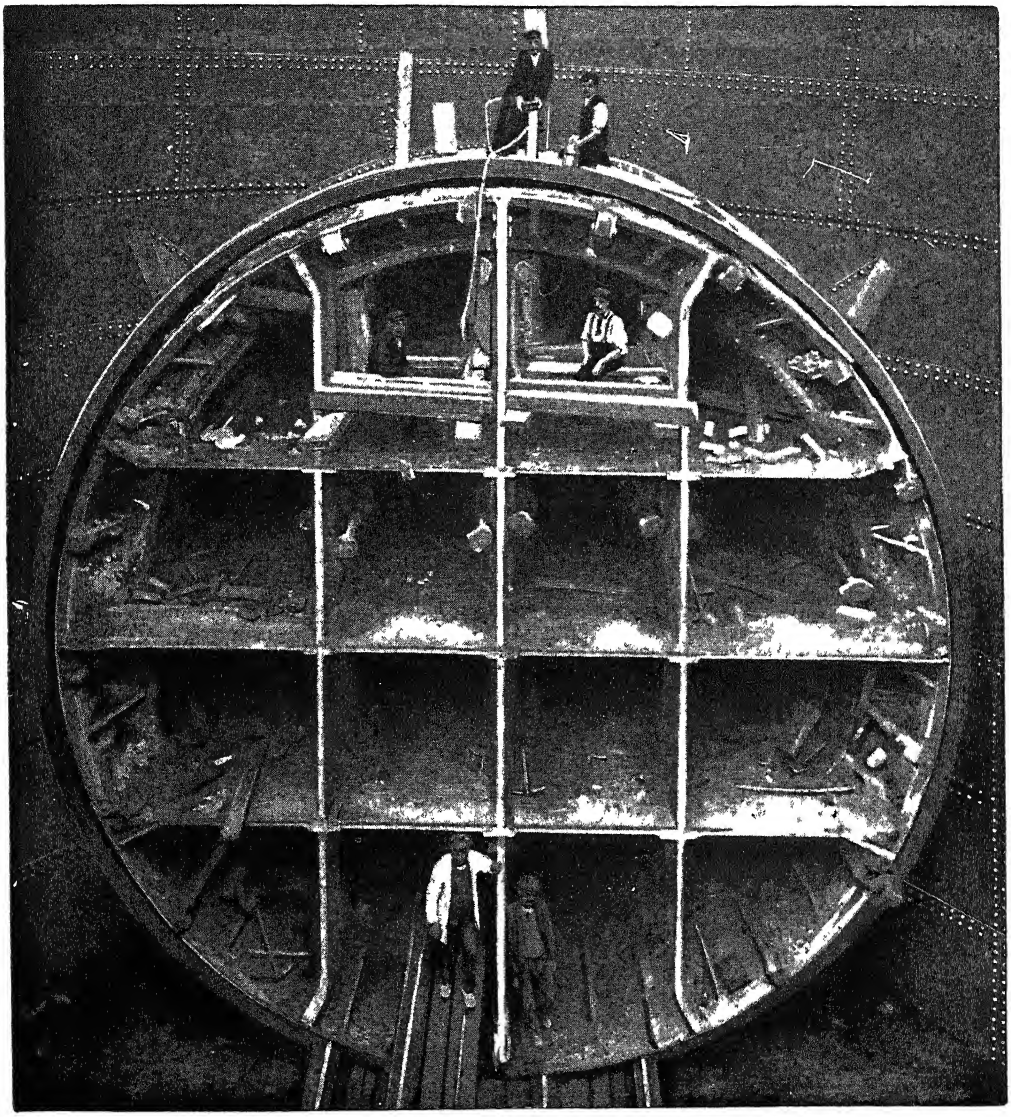
The completion of this tunnel was but one of similar feats accomplished in the 92-mile route along which the aqueduct was led. Upon entering New York City, it was found necessary, on account of the great network of pipes and conduits which already filled the city's streets, to distribute the water by means of a tunnel through the bed-rock which everywhere underlies the city. Accordingly, a tunnel was driven for 18.2 miles under the entire length of the city, with its level in some places as much as 750 feet below the streets and nowhere less than 225 feet. Its diameter varies from 11 to 15 feet, and in constructing it twenty-five vertical shafts were driven to tunnel grade, and headings driven from them. Through these shafts provision is made to bring the water to the distributing mains in the city streets, and by natural pressure water can be thrown 260 feet above tide level. This is undoubtedly the longest rock tunnel in the world.



BACK VIEW OF AN AUTOMATIC SHIELD

When tunnels are bored from opposite ends, as is commonly done, they generally meet with little error at the center. When the Simplon Tunnel was joined up, the walls corresponded exactly, and the height of the floors showed a difference of 4 inches only. And this in a length of $12\frac{1}{4}$ miles! And yet the rails were 175 feet lower at the southern end than at the northern. Moreover, the length, which could not be measured directly, with mountains towering from 5000 to 7000 feet above, was calculated correctly with an error of only 6 feet 7 inches. When the men working from both ends of the St. Gothard Tunnel met at the center, the walls differed only by 8 inches and the floors by half that. In the Catskill Tunnel under the Hudson, the center lines of the two headings met with a deviation of but $4\frac{3}{4}$ inches, and in the Hoosac Tunnel with but $\frac{5}{16}$ of an inch. This is accomplished in several different ways. When vertical shafts are sunk, direction may be obtained from plumb lines dropped to the bottom of the shaft. The weights are made to dip into heavy oil in order to counteract the movement due to deflecting currents of air which rise in the shaft. By dropping two such lines in each shaft, each of which marks a point on the center line of the tunnel, two points on the shaft floor are obtained from which the tunnel line may be run out in either direction by means of transit instruments. These are finely made and firmly mounted telescopes having vertical and horizontal cross-wires inserted in their axis for the purpose of sighting on known points or establishing points on the line of sight. By making many repetitions of each observation, a line is run out into the tunnel heading which will deviate but little from the true center line and this is carried forward from time to time as the line lengthens by mounting a transit on its last determined point and sighting back to another as far distant as can be seen. Finely drawn lines on illuminated white backgrounds are often used for "back-sights". After making one, the telescope is reversed through 180 degrees and the line prolonged.

A variation of this method is used in tunnels which are driven without the use of shafts. A well-determined line on the surface of the ground, along the route of the proposed tunnel, is first obtained. Then at the end of the tunnel transit



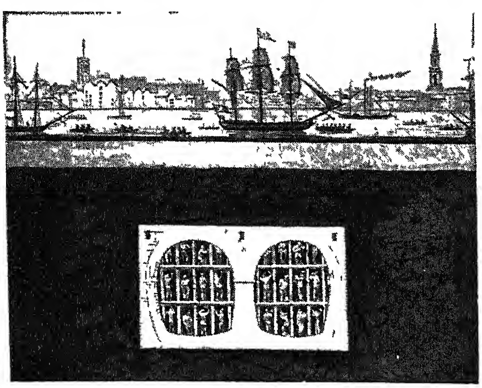
THE SHIELD USED IN THE CONSTRUCTION OF THE ROTHERHITHE TUNNEL

instruments are placed on the center lines, mounted on secure bases. These are backsighted on distant points, previously located on the center line. By a reversal of the telescope through 180 degrees, the line is then carried forward into the tunnel and the headings directed by means of it. An exact meeting at the center of the tunnel necessitates only much care and many repeated observations.

Tunneling in rock, although tedious and often dangerous, is a far different thing from boring through soft material, which carries water in large quantities. This is the condition generally met with when tunnels under rivers and harbors are constructed. Under such conditions, it becomes necessary to prevent not only the caving-in of the soft material but the seepage of the water into the workings.

The caving-in is prevented by means of a steel shield which is driven into the heading by powerful hydraulic jacks and within which the men work with comparative security. The leakage is overcome by forcing air into the tunnel under a pressure sufficient to hold back the water. This air pressure is a serious inconvenience, and even menace to the workmen, but it is safe to say that few of the subaqueous tunnels in existence could have been driven without recourse to this method.

The invention of the shield was the work of Brunel, an English engineer, who took out his first patent in 1818. Brunel's shield has been improved in many ways, and more often the name of Greathead is associated with the first shield, although



AN OLD DRAWING OF THE THAMES TUNNEL IN COURSE OF CONSTRUCTION

this famous engineer only improved upon Brunel's original idea. A shield as ordinarily constructed may be thought of as a huge steel cylinder placed on its side and having a diameter approximately that of the tunnel which it is to build. Its forward edge, which is to be forced ahead into the material to be excavated, is equipped with cutting flanges, and its advance is accomplished by means of hydraulic jacks which press against the rear end of the shield and have their bearing against the final cast-iron or concrete lining of the tunnel which is put in place as rapidly as the shield advances. By means of the shield, no part of the excavation is left unsupported, save at the heading, and men may work within the shield excavating the material and loading it into cars for removal. In short, the shield cuts a clean hole a few inches larger than the tunnel lining, and this hole is immediately filled with an impervious armor of concrete or iron.

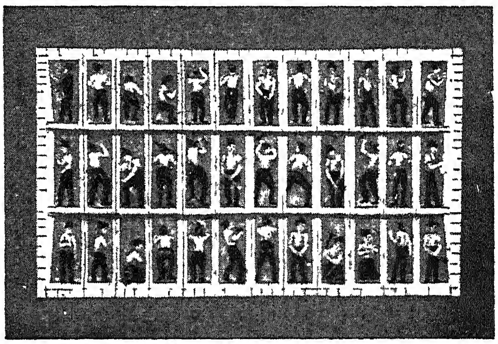
Brunel designed and built his first shield for the purpose of tunneling under the Thames. It was composed of thirty-six independent divisions or little cells, within which the men dug away at the face of the soil, throwing it behind them, from whence it was carted away. A depth of three feet in front was excavated at a time, and the shield was moved forward by means of hydraulic jacks. Then the clear opening of three feet left behind was lined with brickwork. A square passage was thus cut and lined with bricks, 37 feet 6 inches wide and 1200 feet long. Within this, two arched tunnels were built, each 14 feet wide by 17 feet high, connected with cross passages at intervals. The tunnel was driven from one end only, and it was eighteen years before it was opened. It is now utilized to connect the systems of the Great Eastern, Southeastern, Metropolitan, and London & Brighton railways. Other similar tunnels under the Thames, of which there are now twelve, reckoning double tubes, have been constructed in about one-fourth the time.

Shields have been used in all, but not Brunel's. The successive accidents and failures and losses of life and long delays due to the irruption of sand and water from the river overhead would not have happened if the employment of compressed air had been understood and adopted. But the time was not ripe for that. The real era of tunnel-making, done with certainty and safety, dates from the invention of the Greathead shield worked together with compressed air. It was first used in England on the Tower Subway in 1869. That was only about 7 feet in diameter. Its first great work was the Blackwell Tunnel, 27 feet in diameter, which was opened in 1897.

In using compressed air, a heavy airtight bulkhead is built across the tunnel as soon as water is encountered. Air under pressure is supplied to the portion between the bulkhead and the heading.

Through the bulkhead must pass the workmen and all the material excavated. This necessitated a device called an "air-lock", which is, in its simplest form, a space or room built into the interior of the bulkhead. This is entered from either side by doors which are capable of being made air-tight. Upon entering the lock, a workman closes the door behind him and the pressure of the air in the lock is raised slowly until it corresponds to that in the tunnel workings. Upon coming out, the process is reversed, but care has to be exercised lest the men come out too quickly. A trouble called "caisson disease" or "bends" often affects workmen under compression, but, save in exceptional cases, it can be overcome by prolonging the period of decompression. Sufferers from the disease complain of great pain in the joints and act as though paralyzed.

The first use of the shield and compressed air in this country was in building the tunnels under the Hudson River by the Hudson River & Manhattan Railroad Company. Work was begun in 1874 by Dewitt C. Haskins, who sunk his shaft on the Jersey shore and started his tunnels through the silt of the river-bed without a shield, using compressed air and canvas linings to hold back the soft material until a masonry lining could be put in place. A disastrous accident in which the river-bed burst in upon the workmen, engulfing them, put an end to this method, and iron plating supported by timbers was used successfully for a distance of 2000 feet. Then financial troubles fell upon the bold Haskins, and in 1888 work was stopped. English financiers became interested and at their request Sir Benjamin Baker visited the tunnel to make an investigation and report. On his recommendation, financial arrangements were completed, and plans for finishing the tunnel by means of a shield and compressed air were perfected. Work was started in 1890 under most adverse circumstances. The tunnel was full of silt and mud and there was a hole 12 feet in diameter right through to the bed of the Hudson River. It was impossible to get beyond the last bulkhead left by Haskins. After trying many expedients, a device like a plum pudding in a canvas cover, 12 feet in diameter, was put into the hole from above by means of a large floating crane. The door in the bulkhead was then jacked open and the material allowed to leak slowly into the tunnel. This was removed and ultimately it was possible to get by the bulkhead and build a chamber in which to erect the shield. This latter task was most difficult to accomplish, as the plates had to be fitted and riveted, not in a workshop with every appliance available, but in the wet, treacherous end of a 2000-foot tunnel. It is said that the forge fire by which the rivets were heated had a smoke chimney 2 inches in diameter and 2000 feet long, and that the draft was "magnificent". The shield at first gave much trouble by tending to



AT WORK IN THE THAMES TUNNEL IN THE THIRTY-SIX SECTIONS OF BRUNEL'S SHIELD

turn at right angles and cut out for itself a vertical shaft, but finally it was got to going along true lines and nothing happened to stop it until financial troubles again developed in 1891. The work was then suspended, the jacks filled with oil, and everything possible done to leave the work ready for someone to finish. The water was let into the tunnel and there it stayed until 1902, when a new corporation was formed to complete the work. The tunnel was pumped out and after a few alterations in the shield, found intact, progress was resumed. Ledge was encountered and gave much trouble, as blasting ahead of the shield was attended by great danger both to men and shield. Twice the blasts opened the bed of the river and only by dumping scow loads of clay in the hole was the tunnel saved.

The tunnel did not pierce the rock stratum, but only cut into it on the bottom side of the shield and finally a place was reached where the silt above was so soft that it ran like water through the shield-doors. Nothing could stop it until it occurred to the engineers that it might be possible to bake the clayey silt into a hard substance which would not run. Tanks of kerosene under pressure were brought in and flames from blow-pipes were played over the soft clay. After 8 hours of baking, it was found to be hard enough to dig, and work was resumed. Meanwhile, water was played on the shield to prevent damage from the heat. The air pressure at this point was 38 pounds per square inch, making the operation extremely difficult. Seven days later the rock disappeared and sand was reached, through which good progress was made until the shield reached the bulkhead of the short tunnel which had long before been built out from the New York shore. This was March, 1904, thirty years after the first work had started.

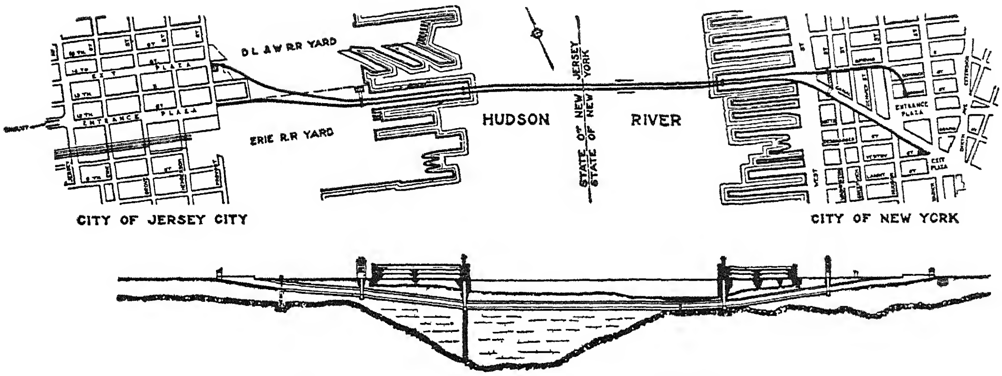
This was the predecessor of four tunnels built by the same company under the Hudson. They were really two double tunnels, separately driven. The experience gained in the tunnel just described enabled the work on the others to be pushed rapidly and with comparative ease as long as silt only was encountered. It was found that with the powerful jacks with which the shield was equipped, it was possible to drive through the silt without removing any of the material through the shield, but simply pushing it aside as the shield advanced. Better guidance to the latter was obtained, however, when a small percentage of the silt displaced was allowed to come through the shield, and this was the method thereafter followed. In 1909 the last of the four tunnels was opened and the dream of a half century realized. Since then the Pennsylvania Railroad and other companies have built numerous tunnels under both the Hudson and East rivers, but it is safe to say that even the great difficulties and hardships of all these combined did not surpass those of the first Hudson tunnel.

Tunnels are sometimes constructed in other ways than have been described. In railway subways through cities a "cut and cover" method is often adopted. That is, an open trench is first built in which the completed subway is constructed. All that then remains is to back-fill the trench, and the work is done.

A similar method has been followed in several notable cases when it was desired to tunnel under a river. At Chicago, for example, the double-track street railway at Van Buren Street was carried under the Chicago River by first building coffer-dams across the river and excavating a trench between them. The concrete tunnel proper was then placed in position, the trench filled and coffer-dam removed. At Detroit, a different and very ingenious method was followed in carrying the Michigan Central Railroad tracks through twin tunnels across the Detroit River. Here the tunnel was actually built in sections on the shore and floated out into their proper positions and sunk to the river bed where a trench had been dug by ordinary dredges and piling driven in its bottom. The ends of these sections were afterward connected by divers, and the steel tubes forming the tunnels were embedded in solid concrete placed about them by means of long pipes fed from a floating scow. The whole work called for the highest type of engineering ingenuity and skill.

The Holland Tunnel

For good reason the Rotherhithe vehicular tunnel under the Thames, and the Hudson and Manhattan Railroad tunnel have long been famous. But great as they are, they are eclipsed in size and as engineering feats by the Holland Tunnel (opened in 1927) under the Hudson River, connecting New York City and Jersey City. The tunnel is named after Clifford Milburn Holland, the engineer who planned and directed the work until it was nearing completion and died a most untimely death because of the great physical strain brought upon him. His able successor, Mr. Milton H. Freeman, suffered a similar fate, and the work was finally com-



PLAN AND PROFILE OF THE HOLLAND TUNNEL

pleted under the direction of Mr. Ole Singstad.

The Holland Tunnel consists of two cast-iron tubes lying parallel to each other throughout the main part of their length but diverging at the ends where they emerge, in order to avoid congestion due to the immense traffic that pours in and out of them and to take advantage of streets already in existence. The tunnel is used by motor vehicles only, of which more than 60,000 have used the tunnel in one day. Each tube is for one-way traffic, wide enough to accommodate two parallel lines of vehicles, the light, fast-moving taking the left side of the roadway and the slow-moving and the heavy trucks keeping to the right.

The shield method of construction previously described was used for driving the tubes, the method of dredging a trench and laying the tube from a floating plant, as at Detroit, not being considered feasible on account of the heavy river traffic. Storms and ice would also delay progress whereas by the underground method work could be pushed continuously.

The north tunnel is 8557 feet long; the south, 8371; under river part, 5480. Quite obviously such a tunnel could not be ventilated by natural means and as will be seen the problem of ventilation was a great factor in the size and arrangement of the tubes. It should be remembered that the impurities in the atmosphere of a tunnel used by motor cars are the products of combustion of gasoline. If complete combustion can be secured these products are largely carbon dioxide, which can be tolerated with safety in considerable volume. But complete combustion never takes place either in a coal-burning furnace or an internal-combustion engine. Due to incomplete combustion the exhaust gases from the motor vehicle always contain varying amounts of carbon monoxide, a highly poisonous gas injurious to health, even if breathed in minute quantities for any length of time. The proper ventilation of these tubes therefore required the drawing off of the burnt gases and the forcing in of enough fresh air to dilute the atmosphere to the point where carbon monoxide would be harmless.

It is apparent that if it were attempted to ventilate by simply blowing air in at one end and permitting it to escape at the other its velocity would be very great: at any point where a truck and an automobile were side by side it would be about 72 miles per hour. Other methods were therefore necessary. It so happens that the circular tube is admirably adapted for ventilation if the cross section has been appropriately designed. The Holland Tunnel tubes are 29½ feet in diameter throughout their length, except that the diameter of one is enlarged near the Jersey side to 30 feet 4 inches, which was the largest diameter for tubes of this kind then constructed. They consist of rings made up of 14 sections 2½ feet wide, bolted together with 10-pound bolts. The weight of each ring is about 16,630 pounds. The tubes are lined with concrete 14½ inches thick, and are divided horizontally into

three parts by two concrete partitions. The lower one is the 20-foot roadway, which is paved with granite blocks and with a granite curb, and with, and a little above, a 2-foot sidewalk for the use of the watchmen who patrol the tunnel. The air space below the roadway is called the fresh air duct and that above the ceiling the exhaust air duct. Each duct is divided into eight sections by cross-walls. In four buildings, two on each side of the river, 84 large fans driven by electric motors draw fresh air down into each of the eight sections of the fresh air duct from which it escapes through slots above the roadway curbs into the tunnel. Simultaneously the tunnel air is drawn through screened openings in the tunnel ceiling into each of the eight sections of the exhaust air duct and thence through separate ducts or passages up through each building and out into the open air. Thus 3,750,000 cubic feet of fresh air per minute is drawn in and completely changes the air in the tunnel every minute and a half.

The main or roadway chamber is lined with white tile throughout its entire length and special care was taken to eliminate all tiles that had tinges of blue, green or red so as to make the inside of the tunnel as light and cheerful as possible. The tiling is bordered with yellow tiles and the ceiling is painted white. It is electric-lighted throughout and the impression is most pleasing. As a matter of fact, driving through it is far more comfortable and safer than on most streets. A water main with hydrants at frequent intervals affords protection against fire, and the entire length of the tubes is patrolled so as to insure against accident and to keep the traffic moving rapidly. The cost of the tunnel was about $50,000,000. Work was begun on October 12, 1920, and on October 27, 1924, the shields working from each side of the river in the north tube came together accurately according to the careful engineering plans.

New York City's Queens-Midtown Tunnel, connecting the boroughs of Manhattan and Queens, was opened November 15, 1940. The tunnel has two tubes: the north tube (westbound traffic) is 6,414 feet between portals, the south tube (eastbound traffic), 6,272 feet. The length of the under-river portion is 3,098 feet. Forty-six fans in two ventilation buildings provide 42 air changes per hour. The estimated cost of the Queens-Midtown project was more than $58,000,000.

LINCOLN TUNNEL, SOUTH TUBE

The Lincoln Tunnel, connecting midtown New York City with New Jersey, resembles in construction the Holland Tunnel. The south tunnel is 8,215 feet between portals and was opened to traffic in December, 1937. The north tunnel is 7,482 feet between portals and was opened to traffic in February, 1945. Each tunnel is 31 feet in diameter and has a roadway width of 21½ feet and a clearance of 13 feet. Before the north tunnel was opened to traffic, both east and west bound traffic passed through the south tunnel, but with the completion of the north tunnel, the south tunnel became east bound and the north tunnel west bound. The tunnel ceiling is of glass tile, the roadway is paved with brick on a sand-cement cushion and the roadway curbs are of steel. Extensive approaches were built on each side of the river, with a new street called Dyer Avenue being constructed in New York and an express throughway being constructed in New Jersey, making a total length along the center line of tunnel and approaches of 21,900 feet. Ventilation is provided by 54 fans. The total cost of the Lincoln Tunnel and approaches was about $80,000,000.

RECORDING THE SOUNDS OF WILD BIRDS

by

ALBERT R. BRAND

Associate in Ornithology, American Museum of Natural History

ONE of the startling attributes of the Class Aves is its ability to express itself vocally. Other animals, both lower and higher in the evolutionary scale, are able to make sounds, but no class possesses that ability to such a marked degree as do birds. No other animal, not even man himself, can produce without mechanical aid, such varied and exquisite music, or can imitate to such an extent the sounds about him.

Among invertebrates some of the insects are noise producers, and a few make sounds of decided musical quality, e.g., crickets. Some fish make primitive noises, but true voice does not appear until we reach the frogs. From frogs upward a large majority of animals are, at some period during the life cycle, decidedly noisy; and they communicate with one another by using their vocal chords. That a number of animal sounds other than man's speech have definite meaning is quite evident, though the meaning is often quite obscure. Prof. A. A. Allen, in *The Book of Bird Life* (D. Van Nostrand, N. Y., 1930) says: "There can be little doubt that the voice in birds has been developed, as in other animals, as a means of communication. This does not necessarily imply an elaborate thought mechanism, nor even an extensive vocabulary, but merely a means of communicating their feelings."

It seems highly probable that voice originated as a means of bringing the sexes together; that it developed from very simple calls, as in the frogs, to the more complex song of birds, the chatterings of the anthropoids, and the language of man Certainly the sounds of birds are a vast improvement over those produced by reptiles and amphibians; and yet some of the more primitive birds make very elementary sounds, not dissimilar to those produced by the lower forms.

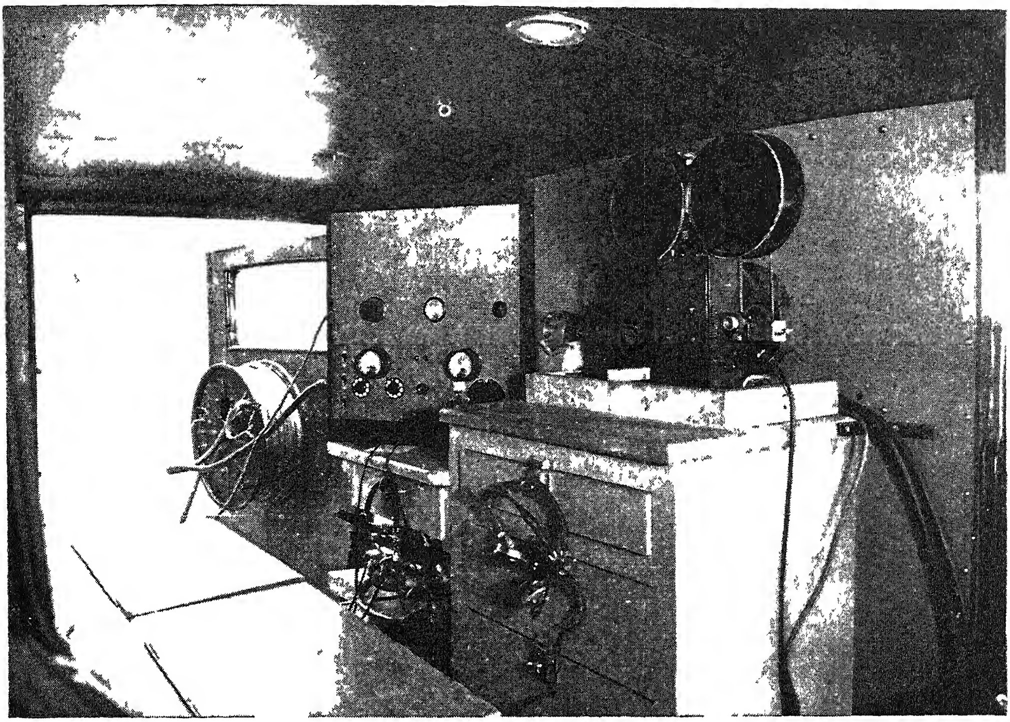
Bird sounds are not merely haphazard utterances without special import. Anyone who has casually observed birds for half an hour can notice that certain sounds are repeated, and that there seems to be some correlation of the sounds and outside stimuli. Watch a flock of Starlings as they gather for the night, and though at first it may appear that all is bedlam, if we pay careful attention to the sounds we shall soon notice that there are certain recurrences; the sounds or lack of them, are repeated. Suddenly for some obscure reason the din will cease. The calls will gradually be resumed, but at first they will be very faint and sporadic, and then will gradually increase until finally bedlam reigns again. The flock will go through this cycle several times, and if carefully observed, the sound would seem to have some relation to the movement of the birds, exactly what that relation is it would be rash to venture to say.

THE TRUCK READY FOR OPERATION

Note the shovel, more than once used to dig the little car out of the mire Photo by P Paul Kellogg.

Though it is obvious that birds, and other animals for that matter, are definitely meaningful in their sounds, it is not so simple to discover just what the meanings are. The difficulties are many, but perhaps the most important is that until now it has been impossible to record carefully and to study systematically sounds from nature. Many methods have been tried, but all of them leave much to be desired Describing in language the songs and calls of birds is futile. Syllables indicating the bird's vocalizings simply do not indicate. Attempts have been made to set down bird song in music, but even here, though results are slightly more satisfactory than by syllabization, insurmountable obstacles crop up. Music is written according to man-made rules. Notations are in definite time; notes are either in whole or half note intervals. While some birds sing, more or less in the conventional scale,—the White-throated Sparrow, for instance,—many more do not. Imagine trying faithfully to translate the bedlam of the flock of Starlings to the musical scale! It cannot be done. Several authors have attempted to make their own notations of bird songs, but even they have to admit that while their work may be an aid, a help in understanding and learning, it is merely a stop gap.

Bird song cannot be accurately studied until we can bring home with us from the field, not notations nor imitations, but the actual song of the birds. Aretas A. Saunders, who has made the most comprehensive study of bird song yet published, toward the conclusion of his book, *Bird Song* (N. Y. State Museum Handbook 7, 1929), says: "Perhaps some day we can devise a phonograph that can amplify bird song sufficiently to record those of wild birds. Then we shall be able to play the record over as much as we like and analyze the song in detail."



INTERIOR OF THE SOUND TRUCK
Showing the wheel of cable on the back door, the amplifier switchboard and control, and (right) the sound camera on which is mounted a magazine of film Photo by Troy Studios

Mr. Saunders was writing in 1929, and though that is only in the very recent past, great strides have been made in amplification and sound recording since then, so that it is possible to do now almost precisely what he predicted. The experiments which are here described were begun in 1930, and they have proved that a machine can be devised that will accurately record the sounds of wild birds. The apparatus has, as yet, not been perfected to such an extent that all bird songs can be recorded equally well; but in two seasons in the field over ninety bird songs, five calls of frogs and toads, one reptilian sound, and a number of mammalian sounds have been photographed and made available for laboratory study. Though not all the bird songs are equally accurate, a sample of almost perfect recording of every important type of common bird song has been secured There is plenty of room for improvement, but it has been shown that the method used is the right one, and that with time and further experimentation it should be possible to record accurately the songs of practically all birds.

In addition to the primary use of bird sound records—that of making bird sound available for laboratory study—there is another use, quite as important in its way, and from a lay point of view of even greater value. To the bird student, whether he be simply an amateur bird lover or a professional ornithologist, a knowledge of bird song is essential. It is through the recognition of the song or call that we are often first made aware of the presence of a bird, and no ornothologist can afford to be without a knowledge of at least the local fauna of birds. The ear hears, and guides the eye. For just as each species is different in outward appearance, though sometimes the difference is only apparent to the careful observer, so each species has its individual song, characteristic of the species, and

"OH, LISTEN TO THE MOCKING BIRD"

The dynamic microphone is set up on a post 250 feet from the truck in an attempt to capture the mocking bird's song

though some birds sing quite similarly, to the trained ear there are detectable differences. But learning the bird songs and calls is not easy; and it is essential—the fundamental step without which one cannot hope to proceed. It is the stumbling block that brings to grief the would-be ornithologist, and many an interested student has given up the study because he could not master this detail For until records are available the only method of learning bird song is the long and tedious one of being constantly in the field. The author remembers not many years ago asking the advice of a man prominent in the field. He answered thus: "There is only one way. Be in the field early and often, in season and out, year after year, and especially during the breeding season. Chase up the originator of each individual song or sound that you do not recognize. It may take you half an hour or more to locate the singer, but what of that? After years of this type of study you will gradually acquire a knowledge of bird song." "But is there no other way?" I asked. "Are there no phonograph records that I can take home with me, and play, and thus become acquainted with the sounds?" The answer was a disheartening negative. It is the hope of the writer that the phonograph records that are being made from the films of bird sounds that he has taken will be useful in aiding the student, that they will make the difficult task a little easier, that, as has been suggested by an enthusiastic friend, they will offer a short cut to learning bird song just as logarithmic tables offer a short cut to mathematical calculation.

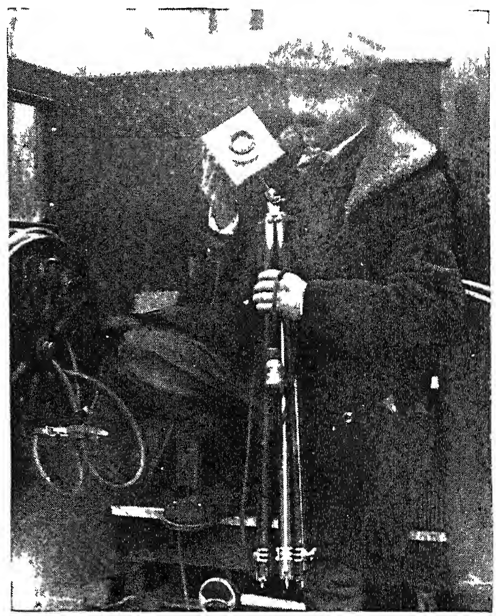
For recording sound in the open it was found that the most satisfactory method was the one that is used by the motion picture industry, the sound-on-film method, or sound photography. The other alternative is to record directly on some form of phonograph record. Though the latter is the most direct, there are limitations to it that make it impractical. To make high grade records capable of reproducing accurately sound of high frequency, it is necessary to first record on wax. Wax recording is extremely delicate work, and requires well trained and highly skilled mechanical operators. Also certain environmental conditions are essential, that are difficult if not impossible to get in out-of-door recording. First the machine on which the wax is to be rotated must be on an absolute level, and must be so set that no mechanical vibrations are produced, for these, no matter how minute, will appear on the wax, and will be magnified and set up as sound vibrations by the record cutter. The wax must be as nearly smooth as possible, and it must be kept at an even temperature, neither too hot nor too cold, not too moist nor too dry. These conditions are impossible to meet, for most bird sound recording must of necessity be done in the very early morning, when the mist is rising, and the temperature changes are likely to be great. Hence recording on wax was ruled out.

This left only the other alternative, sound-on-film, or sound photography. The machine finally adopted can be described best as an adaptation of the sound half of a moving picture location, or "News Reel" apparatus. It was housed in a small Ford truck which had been specially equipped to hold it. The principal parts of the machine were two micro-

phones, several hundred feet of cable, a first class main amplifier, a sound camera, a glow tube, a pair of earphones, and a vast array of dry and storage batteries.

The essential points of this method of recording are as follows: The microphone transforms sound waves into electrical energy, and amplifiers increase the comparatively feeble microphone current to values sufficient to cause a glow tube to flicker in exact correspondence with the frequency and intensity of the sound. This glow tube is then placed in the camera so as to affect a narrow track on the fast moving photographic film. The exposure is made through a mechanical slit .001 inches wide. This slit, permitting light to enter, corresponds to the lens in an ordinary camera, or perhaps a more apt comparison is to the pin-hole in a pin-hole camera. The emulsion side of the film passes over and close to the slit, back of which the glow tube is flickering in exact correspondence to the sound vibrations entering the microphone. The speed of the film is constant; it passes the slit at the rate of eighteen inches per second. Thus the apparatus, theoretically, can photograph as high as 18,000 single vibrations per second, or frequencies of 9,000 double vibrations. Due to mechanical causes, it is probable that the machine is incapable of recording vibrations much higher than 6,000 double vibrations. By studying test film under magnification, and with the aid of a micrometer, it was possible to count vibrations of 4,500 or thereabout. The test film was made by using a child's whistle. The sounds were fundamental tones, and are high as compared to the fundamentals in bird song.

While as yet not sufficient work has been done to make definite statements, it does not seem likely that the fundamental tones of bird songs are as high as 4,500 vibrations. However, bird songs are so high that undoubtedly some of the important overtones which are twice, three times, four times, etc. the fundamentals, come into a range higher than our machine's capacity. Judging, however, from results, bird sounds can be sufficiently faithfully recorded by the sound-on-film method so as to reproduce almost all the common bird songs so that they sound, to the careful listener, identical with the sounds in the open. Studying and mapping out the frequency of bird song remains to be done; for the present, judging only by what the human ear can hear of the sound as it is played back, it would seem that the method used is adequate to produce faithful phonograph records of bird song.



PREPARING THE SET-UP.
The condenser microphone, mounted on a tripod, is being taken out into the woods

In making a sound recording of bird song a cable is run out from the truck to a suitable location for the microphones, of which two are carried, one a condenser, the second, a dynamic. The former is mounted on a tripod, and the operator usually carries the mounted microphone over his shoulder, and takes the end of the cable in the other hand. The cable is carried on a wheel which is attached to the back door of the truck, and it unrolls as the operator goes to the location. There is about two hundred and fifty feet of cable, hence the microphone can be set that distance from the truck. The dynamic microphone, which is somewhat more rugged than the condenser, and which can therefore be handled with more freedom,

THE FLECTRIC EAR
The microphone is centered directly in the beam of the parabola or sound mirror This increases the efficiency about twenty five times and eliminates disagreeable background noises. Photo by M. Peter Keane.

is used in two ways. First it can be taken out as is the condenser, only a tripod is dispensed with. It can be set in a tree, or on a log, or on the ground if need be. It is not quite as sensitive as the condenser, and has to be nearer the singing bird to pick up the song when it is used in this manner.

The second way to use the dynamic microphone is in conjunction with a parabolic reflector. This is a large circular disk-like object, about three feet in diameter, which has been constructed of wire screening as a base, over which a mixture of plaster of paris, glue and hair has been applied. The plate has been finished with several applications of "Duco," which leaves it with a smooth highly polished surface. It is the shape of a section of a parabola, and has the property of amplifying sound when the sound producing object is focused at its center.

The microphone is mounted in a frame eleven inches from the parabolic reflector, and is carefully centered so that it faces the exact center or focal point of the disk-like object. The whole contraption is mounted on a tripod. With the aid of a sighting device, similar to a gun sight, and which is attached to the outer rim of the reflector, it is possible to focus on a songster so that the vibrations produced by the bird's voice are directly in line with the center of the parabola. The magnified sound is then deflected into the microphone. The apparatus has two distinct advantages. First it permits the recording of sounds produced at considerably greater distances from the microphone; and second, by amplifying sounds directly in its beam twenty to twenty-five times, before deflecting them into the microphone, it has the effect of cutting down all other sounds. This last advantage is extremely important, for while the

sound in the beam is received in great volume, all sounds not so focused are received normally. One of the greatest handicaps in out-of-door recording is the presence of extraneous noises, such as wind rush, the babbling of a nearby brook, and the like. For example, on even moderately breezy days, before the parabolic reflector was added to the equipment, recording was practically impossible. A low, rumbling sound, known as ground noise or "ground," was produced, and would appear on the entire recording. This was sufficient to drown out the song of many of the weaker singers, and was unpleasant to listen to even when it did not obliterate the bird song. The reflector had the effect of cutting out or reducing materially these unwanted sounds, for they are received in the microphone in only one twentieth or one twenty-fifth the volume of the sound that is in the beam.

A further improvement was added later. Wires were run out from the truck in conjunction with the cable, when the parabolic reflector was used. A pair of earphones is worn by the man who operates the reflector, thus permitting him to listen in on the bird song as it comes into the microphone. He can then focus on the bird through the medium of hearing as well as by sight, and in practice it was possible to make recordings of birds when, because of the denseness of the foliage, the songster could not be located by sight.

The distance range of the microphone when used in conjunction with the reflector is very considerable. Several excellent recordings were made with the microphone 300 or more feet from the singing bird. As the microphone can be stationed 250 feet from the truck, it is possible to record sounds produced at a distance of over 500 feet from the road. This range makes it possible for us to be in a position to record almost all bird sounds, as there is hardly a bird in the eastern United States that, somewhere within its breeding range, does not approach within 500 feet of a not impassable road.

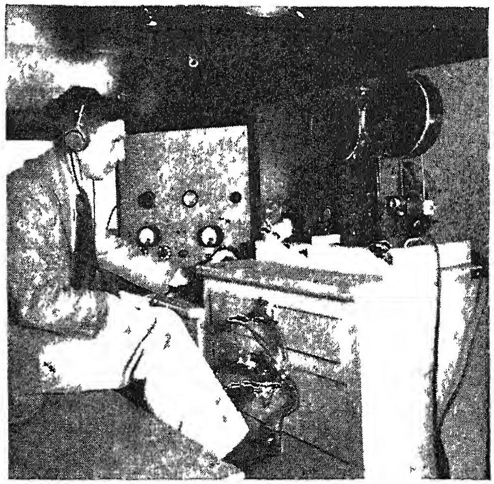
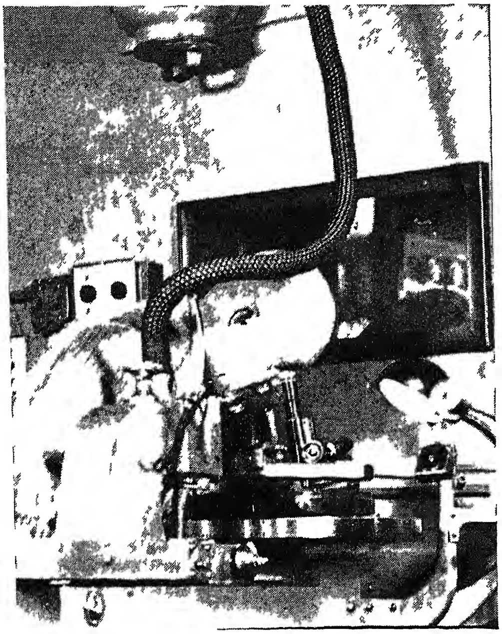


Photo by Troy Studios

LISTENING IN

The sound apparatus in action With earphones on, the operator on the truck watches the monitor board to see that the bird song is being properly recorded

In making a recording, after the cable and the microphones have been set in location and attached, the other end of the cable is plugged into the main amplifier in the truck. In this amplifier the minute vibrations which enter the microphone are enlarged sufficiently so that the increased current can be fed into the glow tube. This is then inserted into the camera. The operator in the truck wears a pair of earphones. A second operator is usually present, although some good recording has been done alone. However, without a second operator the parabolic reflector cannot be used, and the microphones are considerably less flexible than when an outside man is there to change their location, or face them toward the singer, when the temperamental bird happens to change his singing post. The operator in the truck controls the switchboard; he regulates the volume fed to the glow lamp, and the motor that runs the film through the camera. He also hears, through the earphones, the sound which is to be recorded, and listens in while the recording is going on. When he feels that the song is satisfactory and likely to continue, he throws the necessary switches, and the motor starts carrying the film from the magazine compartment containing unexposed film. through the camera.



IN THE RECORDING ROOM
Transferring the sound on film to a wax disk from which the phonograph records are eventually made

It passes the slit, back of which the flickering glow tube is registering by variations of light the sound vibrations picked up by the microphone. Finally the exposed film is deposited in the second compartment of the magazine.

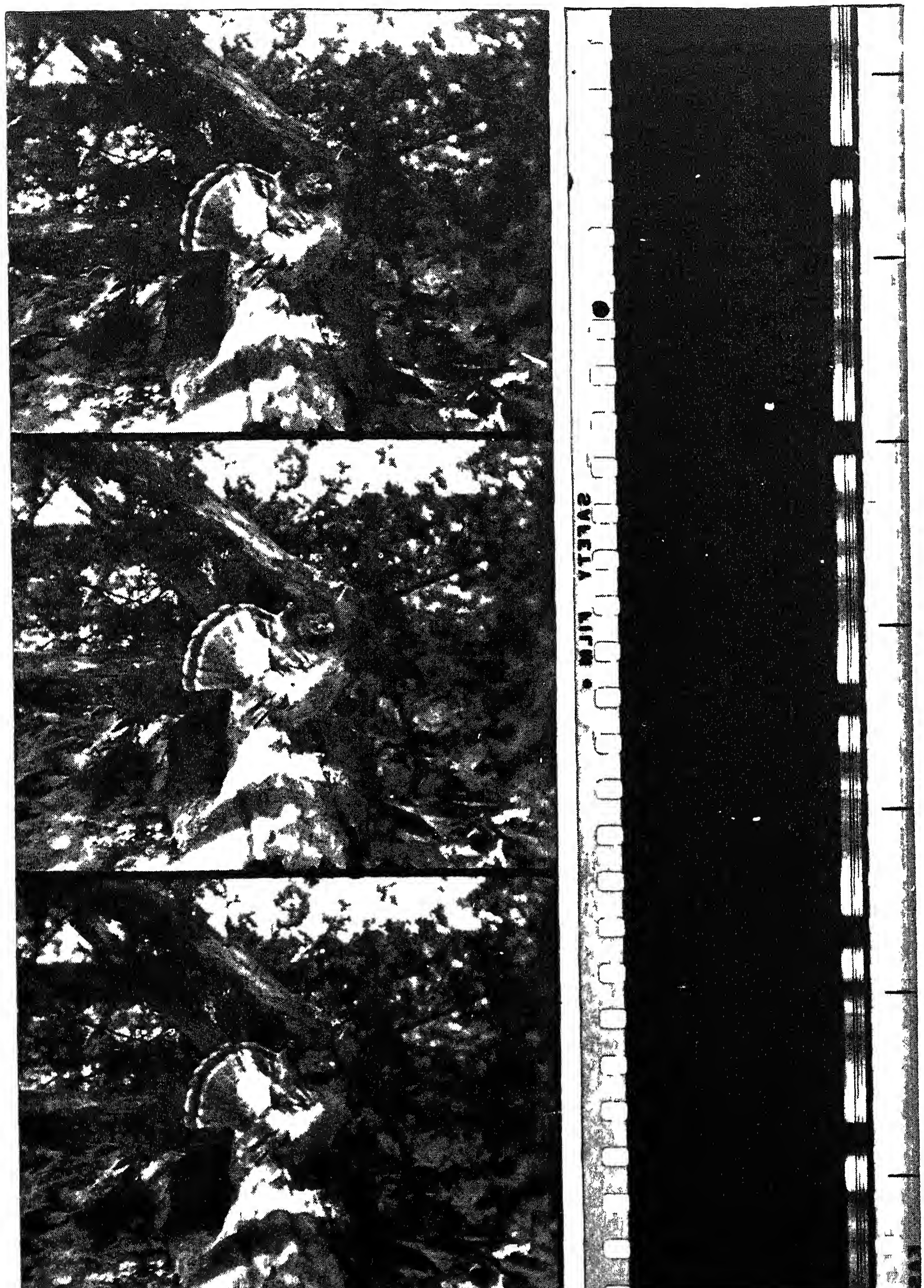
From this point on the technique has been well developed. It is practically the same as that used in the moving-picture- and phonograph-record making industries. The exposed film is developed in the usual photographic manner, except that extreme care must be taken to have the correct density of the exposed track for maximum quality sound production. The track, after exposure and development, shows the various flickerings of the light of the glow tube as fine lines of varying density, running at right angles to the length of the track. The number of these lines and their varying density are what determine the quality, tone, etc., of the sound recorded.

The film is now ready to be played back This is done on a standard sound projection machine such as is used in the motion picture theatres. The film, running through the projector at the same speed (eighteen inches per second) as it ran through the sound camera in the sound photography process, passes in front of a fine slit again; but this time instead of there being a glow tube to make the exposure, there is a photo-electric cell to pick up the photographed sound A brilliantly focused light shines on one side of the track through the fine slit and through the film and into the photo-electric cell on the other side. As the film passes the slit the lines on the track—the photograph of the sound—are made to shine on the photo-electric cell, and the visible vibrations are converted back into electrical energy. As in the recording process, this energy is amplified until it can be fed into a loud speaker, where it is converted back into sound.

The film taken in the field must now be edited. Of about 30,000 feet of film taken in 1931 and 1932, less than 2,000 will be used for making phonograph records. Editing is a never ending task, for it is almost impossible to locate on the film exactly where the song is; and great care must be taken not to apply the scissors in the wrong place, and thus ruin the film. The safest method is the slow and tedious process of playing back the film time and again, until by ear the best recordings have been located. Ordinary low frequency sounds such as human voice or orchestral music are easily seen on the film, but the higher pitched bird sounds are represented by lines that are extremely close together on the film, in fact many of them are so fine as to be almost or entirely invisible to the naked eye. They can best be seen under magnification in a strong light.

For one reason or another most of the film is not good enough for record making. Extraneous sounds—the wind, etc.—account for a large part of this waste. The good is finally sorted from the chaff, and it is then reprinted exactly as a good photographic negative is reprinted. There is one difference, however. In picture making the negative is valuable only as a step in the process of printing the positive; while in sound photography, either the positive or the negative can be used

THE RUFFED GROUSE AND HIS DRUMMING



THE DRUM OF THE RUFFED GROUSE TRANSFERRED TO PHOTOGRAPHIC FILM.

Recording this bird's mating call was a stumbling block, but after spending four nights in the woods the sound recorders were rewarded The bird drums most consistently at the inconvenient hour of 3 30 A M From a motion picture film by Prof Arthur A Allen

for sound production. They are interchangeable, for what is needed is the variations on the film. These, while reversed in the negative and the positive, have the same relation to each other, and as that variation is what determines the sound, negative and positive have the same effect on the photo-electric cell. The reprints are now assembled, spliced together, and as we have eliminated all bad film, we are ready to record the film on wax, preparatory to stamping out the finished record.

The process of making the bird song phonograph records is the same as is used in commercial phonograph record manufacture; except that instead of the sound being transferred from the primary sound source to the wax, it is produced from the film via the sound projecting machine. It is possible, at this time, to partially rid the film of the objectional ground noises that are almost invariably present on all film that has not been recorded in a sound proof room. Electric filters which eliminate the lower frequencies, and which accentuate others, are connected into the amplifier circuit, and the results, if carefully done, are very satisfactory. Great care must be taken, however, not to delete frequencies that appear in the bird's song as obviously this would be fatal. After the wax has been made it is electroplated, and a negative is secured from which records can be stamped out. The records are now ready for use by any student interested in learning bird song. For laboratory study, it is not necessary, or even satisfactory to go through the process of record making. The best material for this purpose is the original, negative film.

The photographic records of bird song have lent themselves well to the study of bird voices. Examination of hundreds of songs shows, for example, that birds do not have notes higher than the human ear can hear, although this statement has often been made. The highest frequencies ever found in bird song are those of the blackpoll warbler and the black and white warbler. Their songs have been found to contain notes as high as 12,500 cycles per second (double vibrations). This frequency is about two octaves above the highest note on the piano.

In collecting the songs of wild birds, the little truck shown on page 3506 and its successors has traveled over 100,000 miles and has stopped in every state of the Union. Ornithologists everywhere, both professional and amateur, have lent a helping hand and an encouraging word to the project.

Perhaps the greatest satisfaction to come to those engaged in the project has been the enthusiastic response of those afflicted with blindness. At times it has seemed that new recordings could not be supplied fast enough to meet the evergrowing demand of this group to learn more about the sounds of nature which open up a whole new field of interest. The American Foundation for the Blind, New York City, has become interested and has already completed a half dozen "talking books," which, with the aid of a phonograph, tell the story of birds and bird life, and at appropriate intervals illustrate the story with the actual song of the bird in question.

Over 300 bird songs have been recorded satisfactorily (1943). Of these, about seventy-five of the best and most frequently heard songs have been made available in an album of six records, published by the Comstock Publishing Company of Ithaca, N. Y. An attempt has been made to group songs which resemble each other so that the differences, though often subtle, will be evident. For example, of the thrushes, the hermit thrush, the olive-backed thrush, the veery, and the wood thrush are found together on the records thus enabling one to enjoy these most beautiful of songsters one after the other, or to study and listen for their differences.

SCIENCE AND SHOE MAKING

The Inventions Which Led to a
Revolution in this Important Industry

RISE OF THE AMERICAN BOOT AND SHOE TRADE

IN most trades of the present day wonderful advances in manufacture have been achieved by abolishing all the old rules-of-thumb, and calling in men of science to discover more exact, surer and more effective methods. In the leather industry, however, we have not yet succeeded in equaling the results of the slow, primitive methods of tanning practised four thousand years ago. Modern science has apparently failed to justify the hopes of the most enlightened of tanners. It is true that modern machinery and modern tanneries are able to produce in fairly cheap abundance the leather goods that serve the immediate needs of the people. Things like boots and shoes and gloves, which are worn out and thrown aside, have become greatly cheapened by scientific methods of manufacture. But, in spite of all the appearance of progress, much of the presumably fine leather supplied to craftsmen in the bookbinding and furniture trades is deplorable. Some of it decays in so short a period as five years. The fact is that a good deal of the leather made since 1830 is bad, and most leathers have got worse since 1860. Practically all Russia leather bindings made during the last fifty years are rotting away; and so are those of morocco leather. Hardly any good, sound calf has been made for eighty years. Ten years of life is the limit for many modern cheap leathers. Some of it loses its color when exposed just for a week to summer sunshine. It is extremely doubtful if any of the work of the famous craftsmen in leather of our days will be known to future generations, for most of it is already fast perishing away.

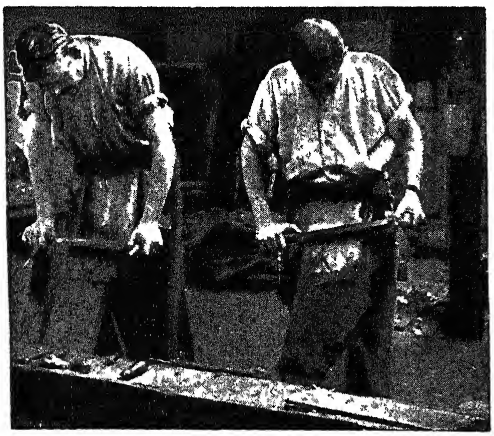
Such is the definite and authoritative verdict arrived at by well-known men of science who have themselves been long and intimately connected with the leather industry. Some of these men have taken a highly important part in inventing and developing new methods of converting the perishable skins of animals into a firm, flexible, and lasting fabric. It is now fairly well known what takes place when a skin is made into leather. The under skin is the part used by the tanner. It consists of the extremely perishable substance of gelatine.

The problem of leather-making lies in discovering some matter which will combine with the gelatine fibers and preserve their flexibility, while making them strong and durable. There are three old ways of doing this. In the most primitive method oils or fats are rubbed into the skin, transforming it into a material as soft at times as fine cloth, and yet extraordinarily durable. This is the way of making chamois leather. Very likely it was known in the Stone Age, and many savages of the present day use it in an admirable manner. When, for instance, a young Zulu desires to marry a woman of his tribe, he has to make a leather robe for her with his own hands. And he dresses the skin of a large beast, now usually a cow, until he converts it into a beautifully soft and exquisite material as pleasant to the touch as the finest and most delicate of cloths. None of the products of our modern scientific tanneries can compare with this work of a savage.

It was also the savage — possibly some Egyptian of the New Stone Age — who discovered the method of tanning leather.

This is done by working into the gelatine fibers of the skin the tannin obtained from the bark or seeds or leaves of various trees and shrubs. In all probability the discovery was made accidentally while trying to dye the skin by some vegetable matter. Color was the thing aimed at, and the marvelously preservative effects of tannin were achieved by chance The astringent bark effected a permanent change in the texture of a skin; it kept it supple; it increased its strength, and it stopped decay. An Egyptian granite carving, probably at least four thousand years old, is preserved in the Berlin Museum in which leather-dressers are represented. One is taking a tiger skin from a tan-pit; a second is employed in another tub; while the third is working a skin upon the table.

These three processes of chamoising, tanning and tawing leather remained in universal use until about 1884 No improvement in the general methods of preparing leather took place from the primitive ages until about 1790, when the use of lime, to loosen the hair from the skin, was introduced. A few years afterwards Sir Humphry Davy apparently proved the fact that the process of tanning was a chemical art, and as such should be conducted with scientific methods So ingenious men began to devise various ways of quickening the slow processes that tanners had used for thousands of years; and good leather gradually ceased to be produced In about half a century from Davy's time the chemist had cheapened leather by destroying its most valuable qualities.



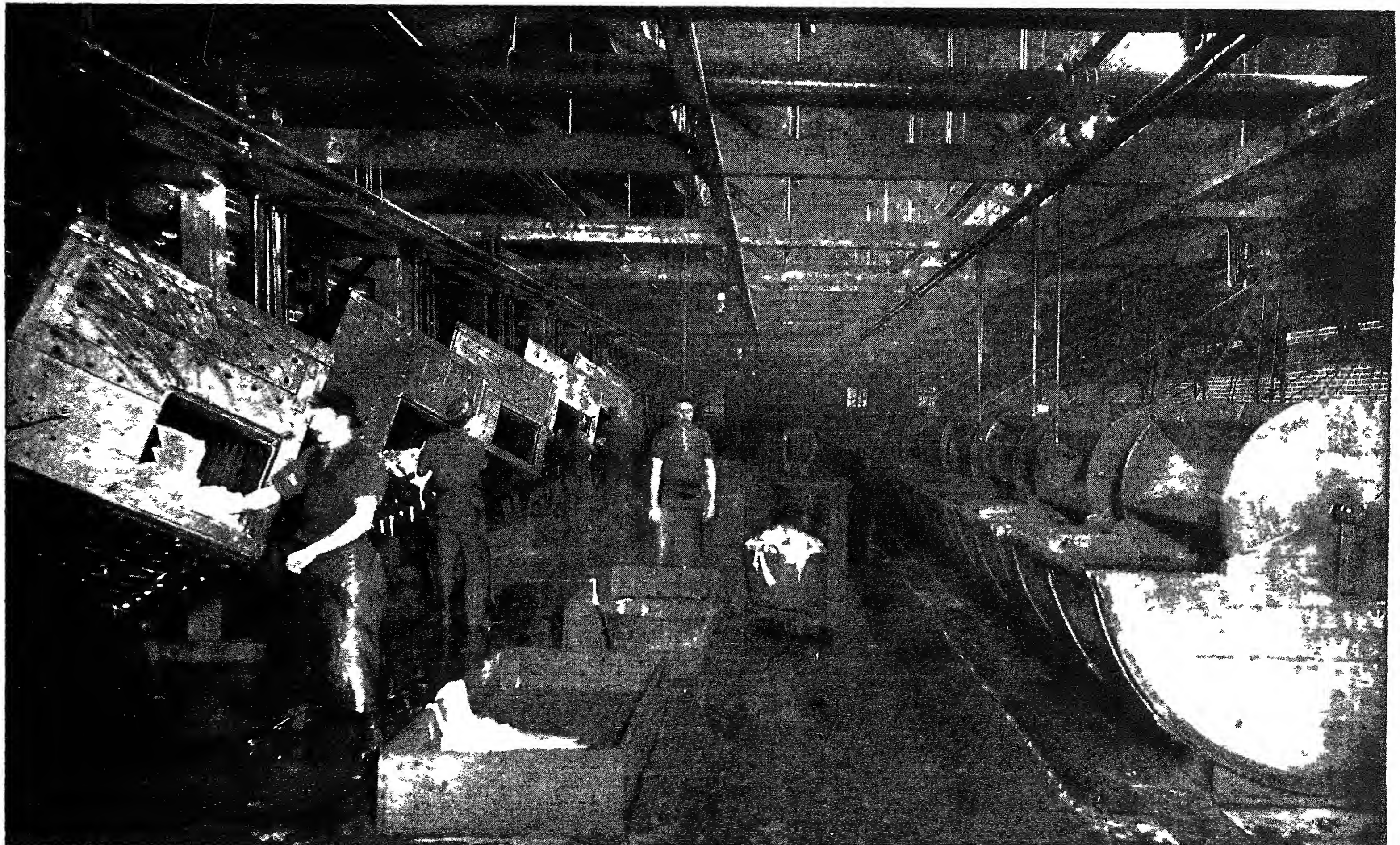
REMOVING THE HAIR FROM THE LIMED SKINS BY HAND AND MACHINERY

Embossed and gilt leather straps are found on some ancient mummies, and an Egyptian boat-cover of embossed goat's leather, as well as shoes of dyed and painted morocco, are still in fairly good preservation In China specimens of leather have been discovered in company with other relics that show them to be perhaps the oldest products of antiquity extant.

Among the Romans the third process of leather-making was practised. In this method a chemical is employed—alum. The process is now known as tawing, and it is used in the manufacture of white leather The skins of kids and calves and lambs and sheep are tawed with alum and salt, and are then made into the upper part of kid boots and the material of gloves.

The plain fact of the matter is that the men of science were wanting in knowledge. What they regarded as a fairly simple matter of chemical calculation was really a problem which was then quite beyond their powers of solving It was largely connected with the mysterious processes of living matter The microbe, not then suspected, much less discovered, often took an important part in helping the tanner to transform a decaying skin into a lasting piece of leather. Moreover, the matter involved the chemistry of complex living compounds, the physics of solution and of the structure of gelatinous bodies — all of which are high and difficult provinces of knowledge that have not yet been fully conquered by science.

THE CONVERSION OF PERISHABLE SKINS INTO LASTING LEATHER BY CHEMICALS



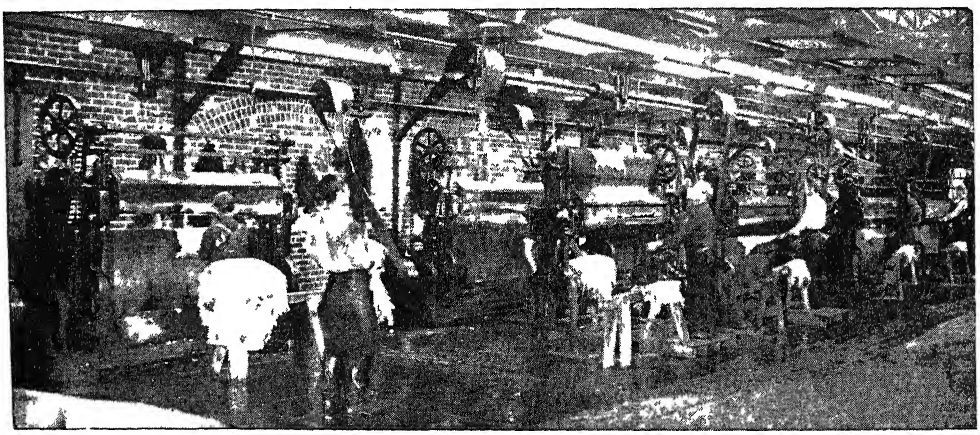
THE TUMBLERS AND PADDLE-WHEEL VATS IN WHICH SKINS ARE IMPREGNATED WITH SALTS AND ACIDS IN THE CHROME TANNING PROCESS

This is why we began by saying that the present position of affairs in the leather industry was very curious and very interesting. The tanner has not received from men of science in the last hundred years the help that Sir Humphry Davy rather rashly promised In the highest reaches of the tanner's craft, modern science has been somewhat of a will-o'-the-wisp, that has led him from the old, winding, and yet safe road, and landed him in a slough. Yet so many obstacles now prevent him from returning to the ancient track that he is compelled to trust in science to guide him further on his way. So chemist and bacteriologist and physicist are now busy endeavoring to help him Already the invisible microbes that he used to use without knowing he was using them are being cultivated in a pure state and sent to him in bottles, so that he can employ them, measured and under scientific control, in his tanyard. Biologists are examining deeply into the wonderful structure of living matter, and especially into the action of organic membranes, and they are making such progress that they will soon be able to tell the bewildered tanner exactly what happens when he combines tannic acid with the gelatine of the stripped skin

But it is the chemist who is foremost in helping the distracted leather-maker This is only fair, because it was he who induced the poor man to abandon his slow but sure, primitive but effectual, methods. As early as 1856 Friedrich Ludwig Knapp, a German chemist, clearly described a method of tanning leather by the action of salts of chromium, but by an extraordinary oversight he did not recognize the practical value of his discovery. He thought that the leather so produced would be greatly injured by water. It was as though a man discovered a mine of diamonds and threw the stones away, thinking they were worthless pebbles.

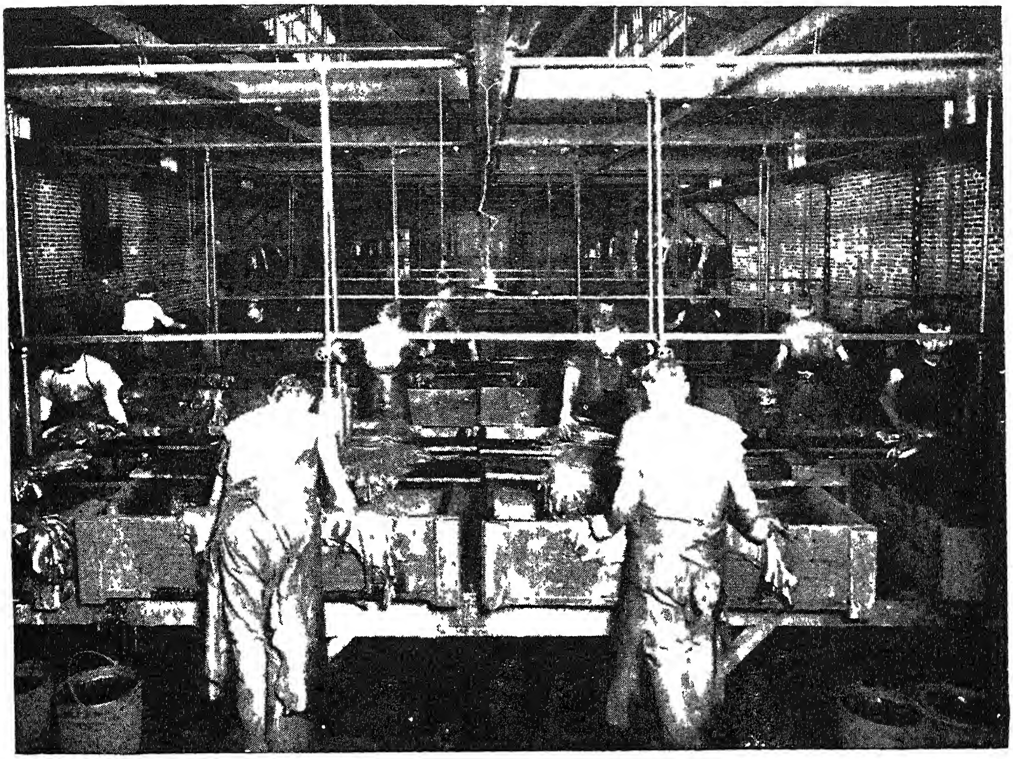
A similar thing happened in England some years afterwards. The late Professor Hummel was asked to dye a piece of chrome leather that was a very ugly color In accomplishing this task, he discovered a new chemical tannage and produced a piece of excellent leather that still remains, in perfectly sound condition, in the possession of the Yorkshire College at Leeds But as there was no legal publication of his invention, room was left for a later inventor to rediscover the means of producing a vast revolution in the leather industry. This was done in the United States in 1884. The result was a rapid development that enabled America to lead the whole civilized world in the leather trade.

Yet here again the event took place in an accidental way. A chemist employed by a New York firm of coal-tar color merchants was asked by a friend if it were possible to produce a leather for covering corset-steels which would not rust the metal as did leathers prepared with alum.

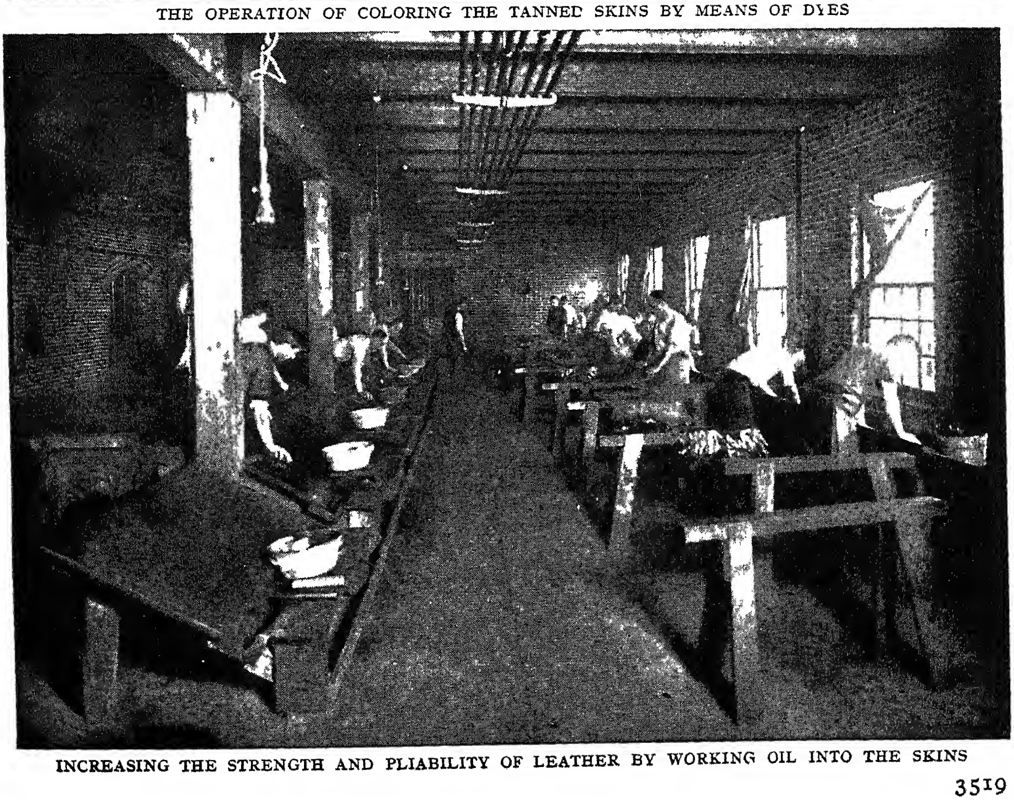


THE STRIKING-OUT MACHINES, THAT STRETCH AND SMOOTH THE GRAIN OF THE TANNED SKINS

COLORING AND OILING THE TANNED SKINS

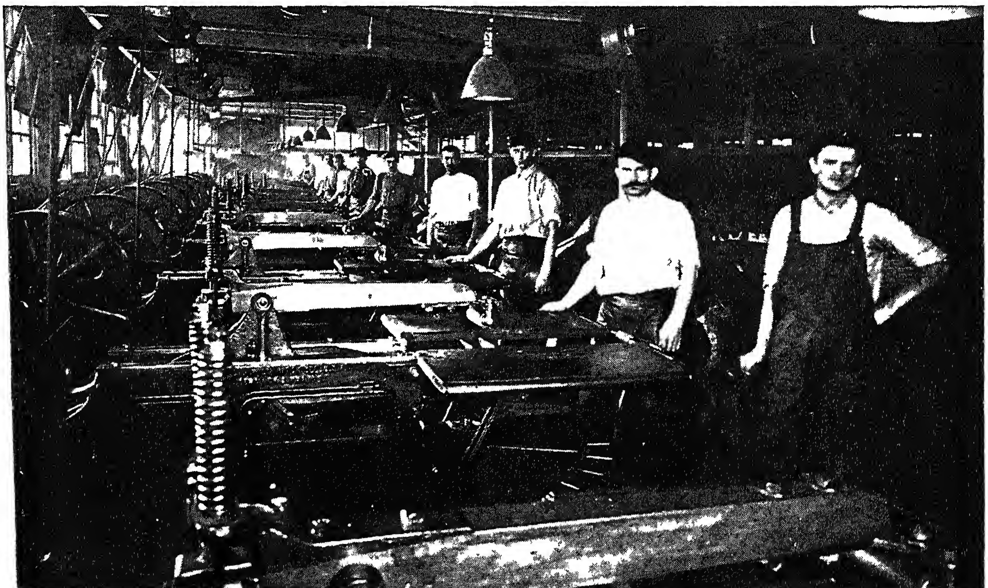


THE OPERATION OF COLORING THE TANNED SKINS BY MEANS OF DYES



INCREASING THE STRENGTH AND PLIABILITY OF LEATHER BY WORKING OIL INTO THE SKINS

Augustus Schultz, the chemist in question, knew nothing whatever about tanning processes His happy ignorance prevented him from distrusting the evidence of his eyes. Instead of being — like Knapp and Hummel — overborne by a wide and intimate knowledge of the gaps and defects of chemical science in relation to leather-making, Schultz brought to the problem the enthusiasm excited by the new coal-tar industries. He took a chrome preparation used in making wool ready to receive an aniline dye. He treated a skin with this chrome preparation, and then put the skin in a bath of the "hypo" that chemists of America had far-reaching consequence on glazed kid, box and willow calf, and on the belting and harness leather industries. The French tanners of light leathers were ruined, and the Americans captured the best of the world's glazed kid trade. The only respect in which the foreign manufacturers could in any way compete was in the old-fashioned tanning of strong, heavy skins for the soles of boots. They could not hope in other grades to overcome the advantages the American manufacturer had gained through his control of the new patented tanning processes.



Courtesy Endicott Johnson Co.

STAKING MACHINES FOR SOFTENING AND TAKING THE STRETCH OUT OF LEATHER

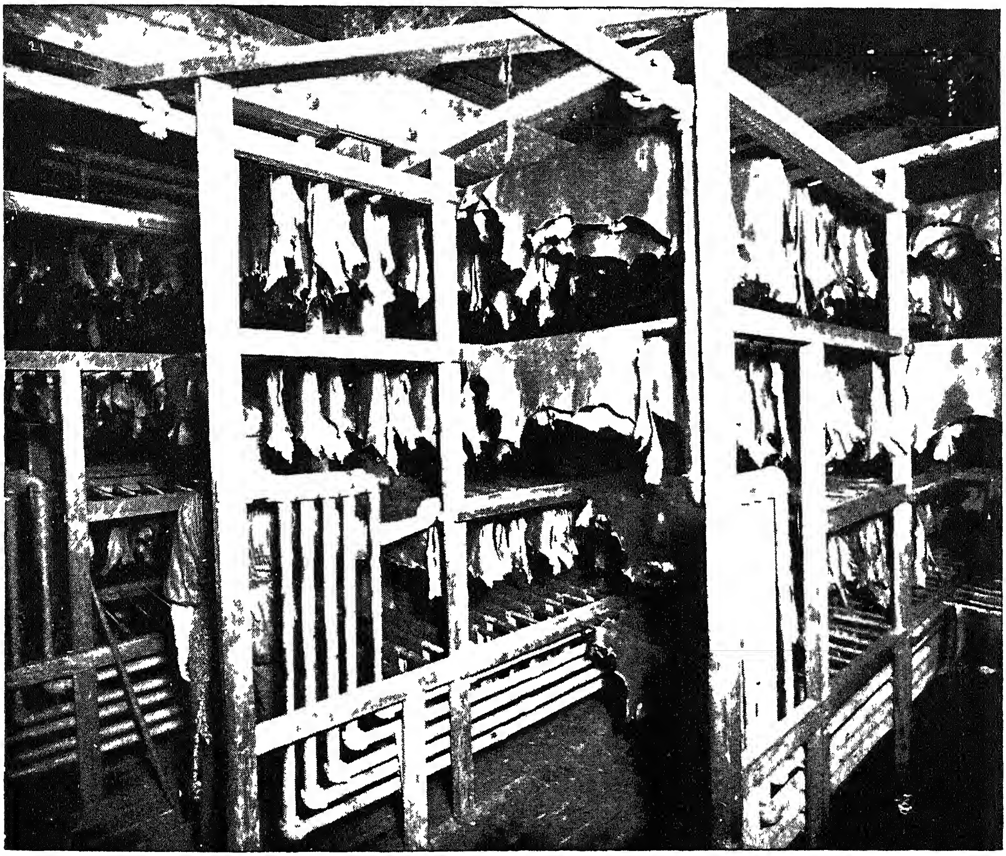
photographers use, and lo and behold the trick was done. Quickly the marvelous importance of chrome tanning was perceived in the United States. Many other American inventors at once set themselves to work out variations of the new chemical tannage, and a powerful trust arose that acquired most of the patents.

Chrome leather, far from being less resistant to water than bark-tanned skins, proved to be wonderfully strong. It was much stronger than any other leather. It could stand boiling water, that destroyed all skins prepared with alum or vegetable tans. The achievement of the technical chemists of America had far-reaching consequence—

Not only did the American possess a surprisingly cheap and rapid method of scientific tannage, but he had worked out a set of extraordinary machines for making boots and shoes out of the new leather. Long before the invention of chrome leather, he had transformed, with remarkable ingenuity, the ancient craft of the bootmaker and shoemaker into a mechanical industry. It was he who developed a method of providing the poorest workers of the civilized world with cheap and good boots and shoes. Three hundred years ago, when shoemaking became a real art-craft, and the shoemaker pro-

duced beautiful works in leather and satin, which for soundness of design and beauty of shape have seldom been equaled and never surpassed, the common people profited but little by the perfection then attained. For we can still see by the pictures and etchings of the time that a large proportion of the peasantry went barefoot. What they suffered from chills and rheumatic complaints and other disabling diseases is not easily estimated. Certainly the want of good boots was one of the causes of the general shortening of life among the working people in the damp and variable climate of Northern Europe. Some of them, it is true, were able to afford wooden shoes, which, stuffed with straw, kept their feet clear of the wet earth; and there were others that wore a foot covering of heavy leather, roughly put together and stuffed with hay. This was the brogue worn by the ancient Britons, and surviving in use in recent years in remote parts of Ireland. It resembled the moccasin of the Indian But in spite of brogues and wooden shoes a considerable number of civilized people went without foot coverings, until machinery began to be employed in making good and cheap shoes.

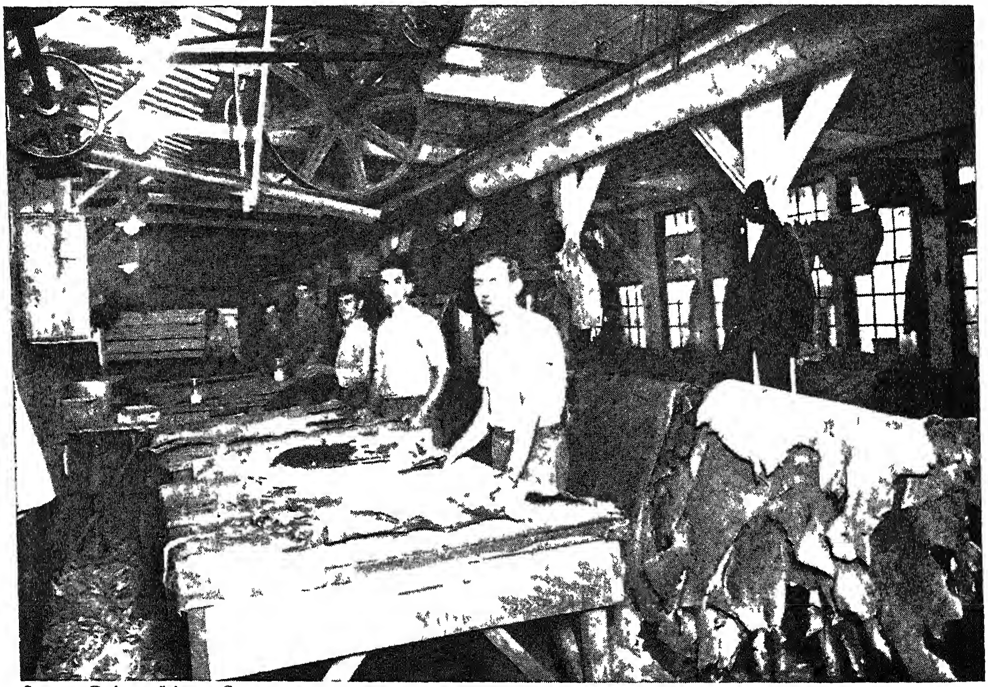
The first piece of shoe machinery, a lasting and soling machine, was made in England a hundred years ago. The English also invented a rolling-machine that cheapened sole leather, by compressing it in a minute and saving hours of pounding. This occurred in the middle of the nineteenth century, but after that date the American inventor swept everything before him. Having made a sewing-machine, he adapted it in various ways to the quick and sound manufacture of boots and shoes, and soon other labor-saving devices were worked out in a practical way in the United States, and applied in factory productions.



A CORNER OF THE DRYING-ROOM FOR STAKED SKINS

Then came an extraordinary stimulus to the development of all these new inventions. The Civil War broke out, and shoes were needed by the armies in vast quantities, just at the moment when the industrial energies of the nation were dissipated in warfare This gave the machine shoemakers their opportunity, and great factories, full of machinery, sprang up and absorbed and extended the manual crafts of the old shoemakers. The transformation of raw material into a finished shoe requires more than a hundred manipulations, but our ingenious inventors at last succeeded in devising machinery to perform practically all of these operations.

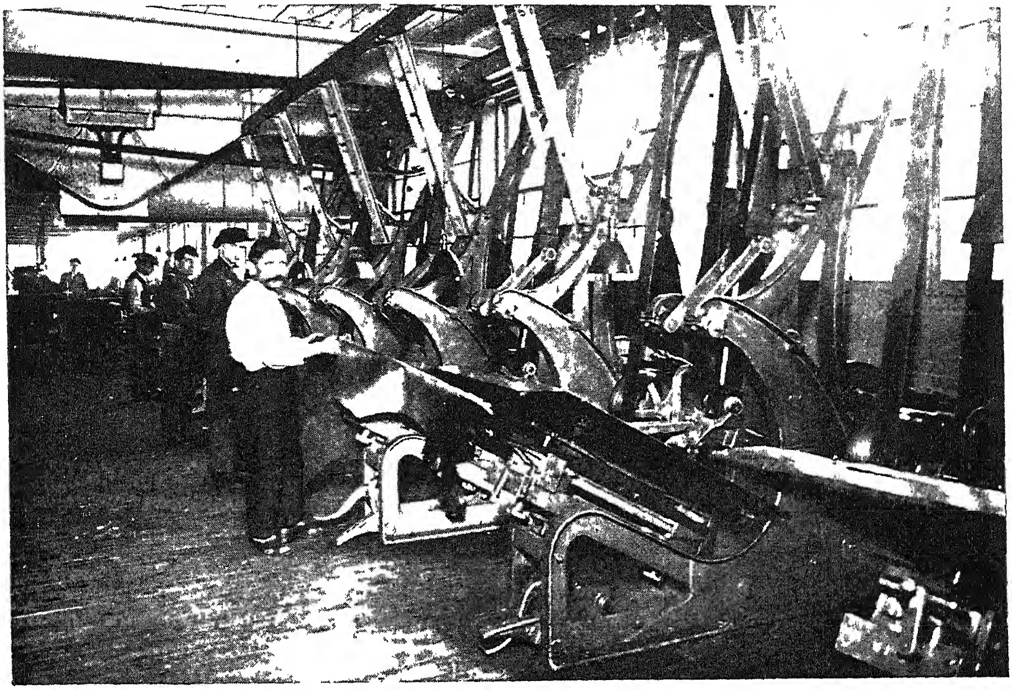
Ancient methods gave place to this marvelous system of machines turning out perfect shoes by the hundred in the time formerly taken by the old-style workman to imperfectly make a single pair. At first the machines for the different operations were made by different concerns, but in 1899 several of them were consolidated into one big corporation, the United Shoe Machinery Company, the largest institution of its kind in the world. This company occupies a unique position in our industrial system in that it does not usually sell its machines but merely leases them to the manufacturer on a royalty basis It takes fifty-eight different machines to make a single shoe, and these are being constantly developed and improved by hundreds of highly skilled inventors employed solely for the purpose. To illustrate the thoroughness with which the American goes about his work, over one million dollars has been expended in developing one single machine — the almost human mechanism that pulls over the upper on the last, in the operation of lasting. Practically all shoe manufacturers in America lease their machinery, and generally prefer to do so on account of the cost, and the rapid developments which often render a machine obsolete in a comparatively short time. Every shoe factory in Europe a few years ago was equipped with machines made abroad, which they owned outright. The majority of them are now equipped with American machines, leased on substantially the same terms as those which prevail in the United States.



Courtesy Endicott Johnson Co

TAKING THE ROUGH SURFACE FROM LEATHER BY HAND

GLAZING AND FINISHING THE LEATHER



THE GLAZING MACHINES WHICH GIVE THE LEATHER ITS GLOSS

Courtesy Endicott Johnson Co

ONE OF THE LAST STEPS — PUTTING THE BLACK FINISH ON A SIDE OF LEATHER

America now makes the best shoes in the world Europe is coming along fast, however, but it is only by putting in American machinery that she is able to compete with American shoes in style and quality.

The development of new adhesives has made cement-attached soles practical, and more than one hundred factories are engaged in such manufacture Cemented shoes were at first widely used for women's footwear, but today light sandals and stout boots are made with this new technique

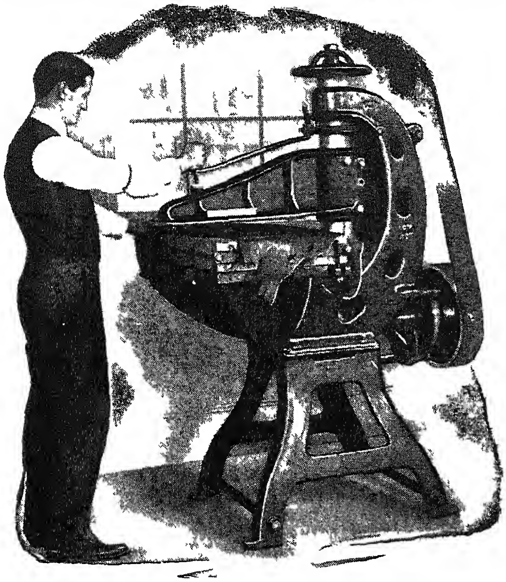
In making shoes a great variety of leathers is used, including alligator, lizard, snake and monkey skins, as well as the more common suede, moose, buckskin, deerskin and patent or enameled leathers. These may be colored according to the demands of fashion, or the purposes for which they are intended. Cloth is also used for shoes and slippers.

The evolution of the shoe in the modern American factory from mere leather and thread to the wonderful product which has contributed so much to the comfort of the world, presents a most interesting study. In many instances a single shoe passes through as many as 210 pairs of hands and 170 machine operations, performed with unvarying accuracy. When an order is received in any well-organized factory of today, detailed instructions affecting the preparation of the shoe are sent to three different departments — the cutting room, where the material for the uppers is prepared, the sole-leather room, where the soles and heels are cut out, and the bottoming room, where all these different parts are assembled in the making or bottoming process In the cutting room, after the kind of leather, linings, stays, etc., required are decided on, the leather is sent to a machine which cuts out dies with all the differently shaped and sized pieces for the upper of the shoe, and marks the vamps for the location of the tip and the foxings, a most important operation. The parts are then passed on to other machines which bevel some of the edges which are to show in the finished shoe, and punch the ornamental perforations along the edge of the toe cap. After the linings are ready, they and the various parts of the shoe are sent to the stitchers, where the different parts of the uppers are united. This work is accomplished on a range of wonderful machines which do the work with great rapidity and accuracy.

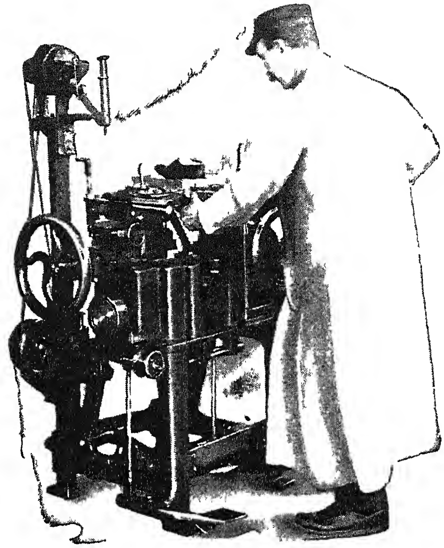
Courtesy Endicott Johnson Co

THE MACHINE FOR CUTTING OUT THE SOLES

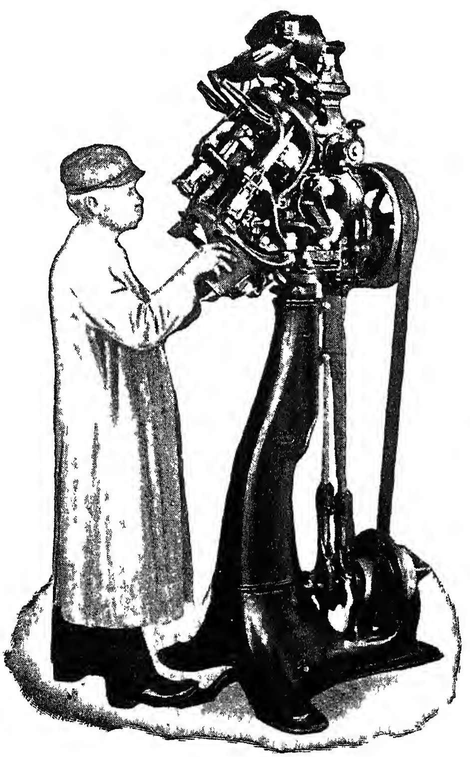
REMARKABLE MACHINES REPLACE HANDWORK



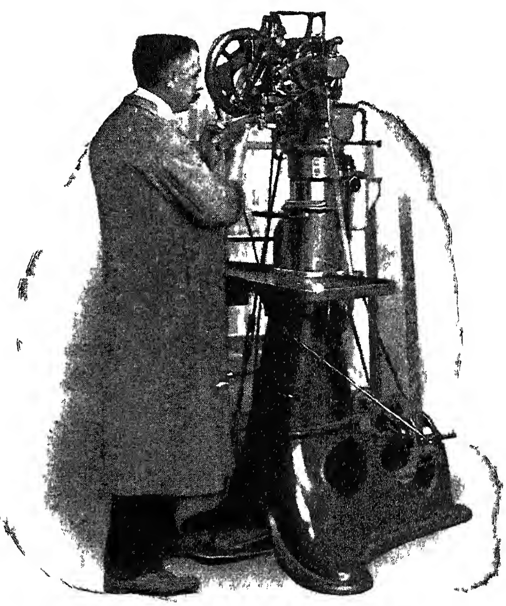
THE MACHINE THAT CUTS OUT THE UPPERS



THE LASTING MACHINE



THE PULLING OVER MACHINE



THE MACHINE THAT SEWS IN THE WELTS

From photographs loaned by the United Shoe Machinery Co.

After receiving the eyelets the upper is ready and is sent to the bottoming room to await the coming of the parts of the shoe which have been preparing in the sole-leather room.

Here the soles have been cut out by powerful machines which force dies of the required shape through the thick sides of leather, and have been submitted to tons of pressure between heavy rolls, and reduced by machinery to an even thickness. The insoles, counters, toe boxes and heels having been prepared by another series of ingenious machines, the different parts of the shoe now begin to meet in the bottoming room. Special machines assemble the parts into the exact position for lasting, a most difficult process which is performed by a machine almost human in the way it accomplishes its task. The shoe next receives the welt, a narrow strip of prepared leather that is sewed along the edge of the sole. The remarkable machine which stitches the welt, the upper and the sole together has been the leading factor in the great revolution which has taken place in shoe manufacturing.

After receiving the heel and after operations of trimming, rounding and leveling, to remove irregularities, the shoe is now nearing completion. The soles and heels are stained and given a high gloss, and the entire shoe brought to the required finish by various polishing and buffing devices. All this time the last over which the shoe was drawn early in the making process has been allowed to remain, so that the finished shoe, having acquired, may retain exactly the shape desired. The last is now withdrawn, and after a few minor operations the shoe is packed in cartons and is ready for the wearer. In every part of the world where shoes are made this same process and the same machines are employed, varying only in unimportant details.

Courtesy Endicott Johnson Co

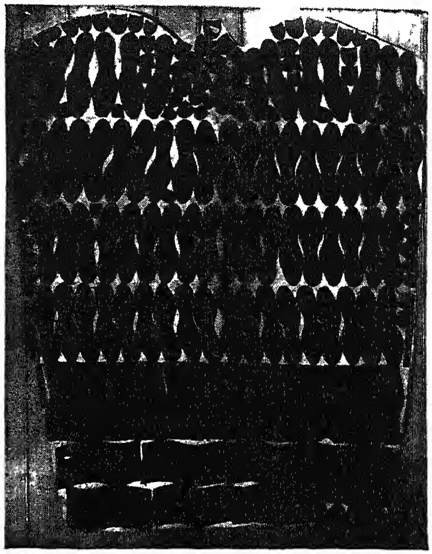
STITCHING ROOM WHERE THE DIFFERENT PARTS OF THE UPPERS ARE SEWED TOGETHER

The result of our early control of the industry was that the poor in America were provided with cheap and good shoes long before the similar class in other countries were able to afford them. In ancient Egypt the rank of a person could be at once recognized by observing the way he was shod. The nobility wore shoes embroidered with gold and studded with gems, and each descending class indicated its social rank by the material of its footwear. Indeed it was prescribed by law.

Until a few years ago the shoes worn by the different classes in our modern society were almost as significant of the social positions of the wearers as were those of the ancient Egyptians. In the United States, however, shoe-machinery and chemical tannage of leather gave a democratically uniform appearance to the feet of the people.

Armed with labor-saving and labor-cheapening machines and his new chemical processes of leather-making, the American sailed across the Atlantic bent on supplying Europe with his well-shaped and smart-looking shoes. Instead of producing a few stock sizes, as was the custom of European manufacturers, he used pattern lasts for practically every shape of foot. Small variations in width and length, and combinations of these variations, enabled him to fit every customer with a cheap shoe that was almost as well molded upon the foot as if it had been hand-made to measure. American boots and shoes ousted the plain and cumbersome product of foreign designers and manufacturers who were not able to withstand the invasion. Thus the shoe trade of Europe was revolutionized by American inventive genius; although, due in great measure to further improvements of tanning processes by English scientists, the industry in Great Britain has also undergone a remarkable development from within.

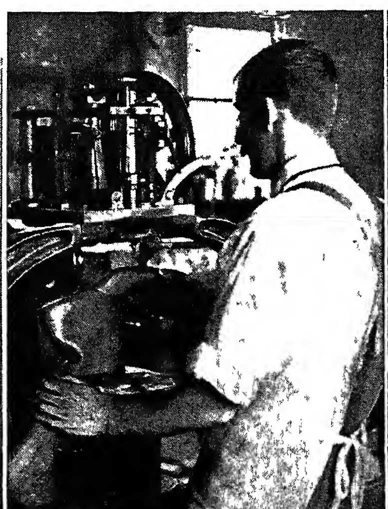
Originally the small tanners depended for hides upon the surrounding country, but with the advent of the railroad and the steamship, and the application of chemical science, the tanner of today is dependent upon no one country nor any special animal for his raw material. The heavy hides are obtained from oxen, cows and horses, while the lighter ones come from calves, sheep, goats, deer, pigs, seals and from various fur-bearing animals whose pelts usually retain their hair after tanning.



A TANNED SKIN CUT UP FOR SHOES

There is no waste in the boot and shoe industry, every fragment left between the shapes cut out is used in making up the heels or is worked up into a composition

ATTACHING THE SOLES

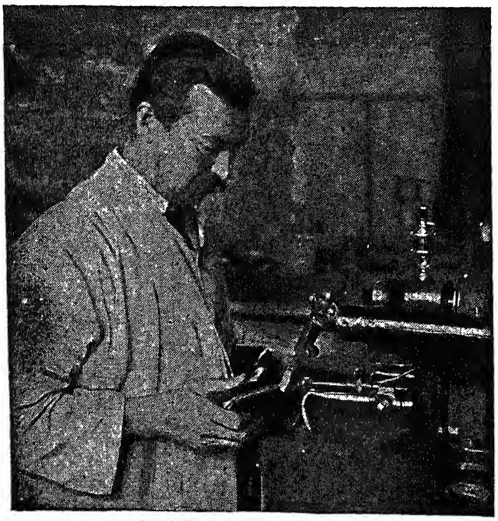


STITCHING ON THE SOLES

FIXING ON THE HEELS

In America the small hides of the cattle of our western plains make much stronger leather than do the hides of the big beefy cattle of the East. The skins of our mountain sheep and of the sheep of the Patagonian uplands of South America also are thicker than those of woollier and more carefully tended flocks. In Europe the cattle of the Bavarian uplands and the Pyrenees produce the finest hides; and it is from the unsheltered goats roaming the Saxon highlands and the Alps and the Pyrenees that skins of the lightest and yet toughest grain are obtained.

In regard to our shoemaking trade, the United States annually imports large quantities of the kips of yearling cattle of foreign countries. A kip, we may explain, is merely the hide of a young beast. Taken from small, young cattle, and tanned by the chrome process, the kips make excellent material for the uppers of men's shoes. A good deal of the kid that is now used in women's shoes is manufactured from sheepskin, which, when tanned with chromium, produces a passable imitation of glazed kid. Very little sheepskin is nowadays sold as sheep leather, though sheep leather, when properly made, is very durable and flexible. But somehow it has gone out of fashion. So the tanner converts it into various imitations of other leathers. Even the innocent little lamb masquerades as a kid in the modern leather industry.




FINAL OPERATIONS IN SHOEMAKING — TRIMMING AND SCOURING THE SOLES

The imitation grained leathers made from sheepskin are among the most perishable products of the modern tanyard. If the scientific tanner devoted himself seriously to the task of making a leather from the pelt of the sheep, in which the natural qualities of the skin were retained, the so-called kid gloves of the cheaper sort, which are really made from sheepskin, would wear much longer than they do now.

We do not now depend so much on leather as men did in primitive and barbaric ages. To various savages there is still nothing like leather. Of cured skins they make the tents in which they live, the shields wherewith they fight, the clothes they wear, and sometimes, as with our ancestors, their drinking-vessels are made of skin, their armor of hard leather, and their shoes of softer leather. We have gradually found better materials for many of these things. Yet leather belting is often necessary in our latest machinery. The small leather bag has freed women from the necessity of having pockets in their dresses. With increasing luxury, the glove, that is useful in winter, has become a social token to be worn, or at least displayed, on the hottest summer day. The automobilist and aviator have brought back the leather dress of our primitive forefathers, and the high-class motor-car is upholstered in leather, as is also a considerable amount of modern furniture.

THE SEA-FISH WE EAT

The Strange Life Stories of Sea-Fish
Which Come as Food to Our Tables

ILLIMITABLE RESERVES OF FOOD FOR MAN

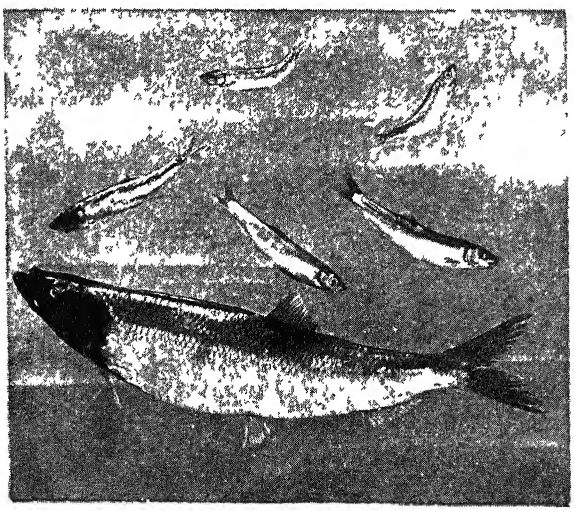
THE naturalist has followed the fisherman to sea, and is teaching, guiding and controlling him. The fisherman's policy is to take all out that he can, regardless of tomorrow. The naturalist teaches him the importance of conservation of natural resources, stays his hand in its grasp of immature fish, instructs him in the art of increasing the store upon which he has to draw. The natural bent of the fisherman is to retain all that comes to his net, and to dispose of that which cannot go to the food market as fertilizer for the farmer's land, or offal to the sea. He scorns, if left to his own devices, the fact that the cargoes of immature fish he thus throws away might, if permitted to mature in their natural habitat, suffice to repopulate the seas, to his own immense advantage.

The United States Bureau of Fisheries is charged with the investigation of fluctuations in the supply of fish, and the development of methods to regulate and cultivate this supply in the interest of conservation. It operates fish hatcheries for the propagation of useful food fishes which are distributed in suitable waters.

Naturalists have gone to the fishing-grounds and sought by tests to estimate the number of fish spawning in the North Sea. Henselt and Appstein have presented figures as to the more familiar denizens of the deep which suggest a good deal of thought. During the spring of their investigations, they estimated these numbers, in millions of fish, as follows: cod, 44; haddock, 180; plaice, 103; flounders, 38; dab, 840 — a total of 1200 million of mature female fish. To this must be added 430 millions, the estimated number of mature male fish, plus the total immature fish of both sexes, 8180 millions. The grand total of the fish in question would thus be, in this one area, an unimaginable 9800 millions.

It is probable that these figures underestimate the actual totals. When we reflect that in three months in 1911 no fewer than 854 million herrings were landed at two English ports alone, a number greatly in excess of all records for any entire preceding herring season, we see that no calculation could have provided for such figures. Mackerel, too, probably exceed by far any sort of estimate that we are likely to have to consider. One particular fleet, a few years ago, ran into a "sea" of mackerel fifty miles in circumference, and other fleets missed it. Now, mackerel in their shoals pack so tightly that they have been seen almost to suffocate a grampus which dashed into their midst. Who could number with accuracy this unthinkable host, fifty miles in circumference? And this was only an isolated group, the massing together of the progeny of a certain number of fish, all approximately of the same age and size, and unable, therefore, to destroy one another. The seas are not inexhaustible, but it is unlikely that we know as yet anything like the actual number of their inhabitants, which vary so much between a favorable and a bad season for hatching as to defy the summing of the observer.

The ordinary fisherman is not the source of information upon which we can rely He has still to be taught his business, not as to how he shall shoot his nets or land and cure his catch, but, as we have said, how he shall make that which is already mighty in number still mightier, by nursing the children of the seas as we nurse the product of the garden, the orchard, the vineyard and the field. Little by little we are extending our knowledge of the conditions and possibilities of sea-fish life, and have reached the conclusion that man may improve upon the methods of nature in the waters as he may upon the land. He transports fish from one sea to another, restocks depleted waters, creates new sea populations. But, although it is striking enough that eggs should be taken, packed in ice, from one side of the world to be hatched on the other, and that here, there and in every civilized land man should be constituting himself the foster-parent, as it were, of various fishes' young hopefuls, there seems something even more challenging in the latest scheme — the putting of little fish out to nurse. It has been done so far in only a small way, but the result is very significant. Small fish have been caught in shallow inshore waters and carried out to rich deep-sea feeding grounds. These experiments made with marked fish by eminent naturalists show the following returns.



A HERRING AND WHITEBAIT

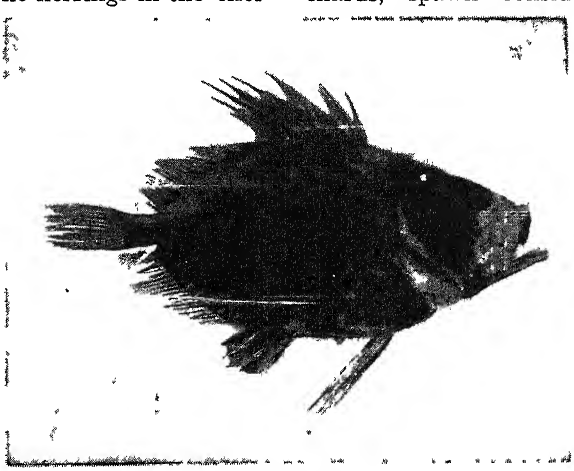
From an average length of $8\frac{3}{4}$ inches, transplanted fish grew in one year to 14 inches, whereas those not transplanted increased only to $10\frac{3}{4}$ inches. In weight the increase of the transplanted fish was 382 per cent as against 100 per cent for the others. We have here a beginning, and only a beginning, just a mere hint from science to those commercially interested in sea-fishing, but the possibilities are obviously infinite. Some day, when science and the fisherman reach more than a nodding acquaintance, we shall have as sane a system of conservation of sea-fish larvæ, possibly even to some extent of fish eggs, as we have in regard to salmon, trout, oysters and, by a later development, lobsters.

Heavy as are our supplies of fish, the demand will grow as facilities for its inland transport are improved. Experts are unanimous in their advocacy of fish as a beneficial diet; and when transport methods render it possible for the fruit of the seas to reach the crowded country areas in fresh and healthy condition — which is not today possible — the industry of the fisherman will be an increasingly profitable one, attracting enhanced numbers of men, and still more expeditious and wholesale, but more prudent, methods of capturing the fish It will then be absolutely imperative to take steps to safeguard and, if possible, to increase the source of supplies, and the transplanting experiments suggest what may be achieved by systematized effort upon a wider scale. Let us glance at some of the most important families of fish from which our food supplies are drawn.

The herring is a member of one of the most important of these families. Were they scarce enough to sell for a dollar a piece, they would rival in favor the salmon, to which anatomically they are closely allied, though naturalists are far from unanimous as to including them in one family. The accepted plan is to brigade the herrings with the sprat, the pilchard, the anchovy and a couple of shad as the family Clupeidœ.

The herrings themselves are common to both sides of the northern Atlantic, and range eastwards to the seas on the north of Asia. They deposit their eggs near shore, where they sink after being fertilized, to hatch out upon rocks and the sea-bottom. Innumerable millions are destroyed by fish, by crustaceans and by nets, but on the whole the plan has as many points in its favor as that of the eggs laid at or near the surface. Shad, too, sink their eggs, and these might on the whole be thought to have the better chance, for whereas the ova of the herring adhere in clumps, insuring disaster for a whole group where one is attacked, the eggs of the shad develop singly.

The massing of the herrings in the enormous shoals of which we frequently read has provoked considerable speculation. No fewer than 320,000 have been taken at a single haul by one boat. One painstaking investigator reached the conclusion that the herrings swarm in myriads the better to protect themselves against their large enemies, one of which, engaged in an attack upon one of these colossal shoals, runs the risk of suffocation or death, much as used to happen to beasts of prey which strayed into the line of march of the multitudinous springboks And he cited a rorqual which he saw in extremities in such case. Hampered by the enormous mass of its prey on attempting to rise to breathe, the whale had to leap clear of the water to effect its purpose. This he mentions as proof of his theory that there is safety in the numbers of herrings. But a similar phenomenon may be observed wherever herrings swarm. They are followed by flocks of predaceous sea-birds and by schools of whales, feeding with as little danger as birds and beasts of prey feed upon a migrating host of lemmings The whales do have to leap into the air at times to breathe, but that is their business, not an accident. The best explanation seems to be that herrings, hatched at about the same time over a wide but connected area, assemble, as birds and as mammals of many kinds assemble, because each and all are inspired by one idea — the search for food, that is to be gained in a certain direction towards which instinct guides them.



A JOHN DORY

Needless to say, the "hard roe" of the herring comprises the eggs of the female while the soft-roed herring is the male. Certain other table fish, such as the pilchards, spawn considerably further at sea, hence we do not get roes with these, their spawning-grounds lying beyond the range of the fishing-boats.

Herrings are an ancient generalized type, connected by extinct species with the ganoid fishes, of which the sturgeon and bowfin of today are examples. They are sea-fish in the main, but can take to the brackish waters of tidal rivers, and Australia has true fresh-water herrings, which are survivors of a stock that once haunted the waters of both the Old World and the New. Male herrings are believed to be slightly in excess of the females, which is unusual in fish life, as in other phases of the scheme of creation One male is capable of rendering fertile the eggs of several females, and investigations among the denizens of the deep show that females largely preponderate as a rule, to which, however, the herring is not the only exception.

Whitebait, which is so highly prized in England as an article of diet even by many who would scorn to eat herring, are simply the young of the latter fish and of sprats

together with a few others. All are whitebait once they have reached the net. The sprat is abundant on the Atlantic coasts of Europe. It is about half the size of the herring and deposits some five thousand eggs, close inshore, and sometimes even high up estuaries.

The anchovies are closely related to the herrings and are sometimes called dwarf herrings. As a family they are small, compressed and delicate, and their weak musculature, together with their soft bones, render them tender and oily. They are often preserved in oil and ground into a paste, which is highly prized as a delicacy by many. Frequently anchovies, small herrings and similar fish are collectively called sardines and placed upon the market under this name. In England young pilchards, also members of the herring tribe, are likewise sold as sardines. Under the sardine label the marketing of several varieties of small fishes is permitted legally.

The shads are another family that are much prized as a source of food. Although essentially marine fish, they ascend rivers to spawn, though not apparently beyond the limit of brackish water. Like the herring, shad feed chiefly on the minute organisms suspended and floating freely in the sea water, which are collectively known as plankton. Though native to the Atlantic coast, shad have been introduced successfully on the Pacific coast.

Another important salt-water fish is the sea bass. There are about four hundred known species, most of them inhabitants of southern waters. The striped variety

N. Y. Zoological Society

A splendid specimen of the fishes known as wrasses.

Florida State News Bureau

The tarpon is noted as a fighter and as an acrobat.

is a most valuable food fish averaging from one to one and a half pounds in weight. It inhabits the waters as far north as Massachusetts and as far south as Florida, feeds upon fish and the larger crustaceans — including lobsters and crabs — and ascends rivers, or enters bays, to spawn. The striped bass has also been introduced with success on the Pacific coast, where it is now of considerable importance.

The squeteague, or weakfish or sea trout, as it is often called, is well known in the fish markets of the Atlantic coast from Cape Cod southward. These fish travel in large schools and are captured in great numbers along the coast and in the bays of the southern states. The eggs, which are deposited over a long period in spring and summer, float on the surface of the water and hatch in three or four days.

Another esteemed food fish is the John Dory; its curious name is believed to be

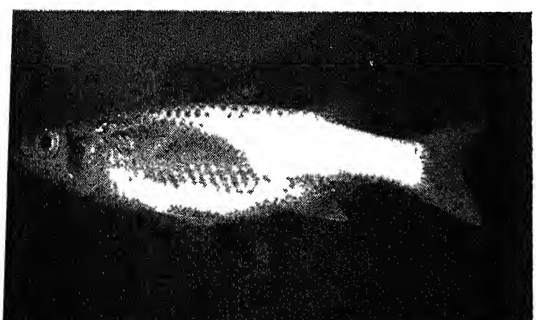
a corruption of the old Gascon *jan dorée,* meaning "gilded cock." It attains a weight, when full grown, of at least eighteen pounds. The laterally flattened form of the body, which looks so strange out of water, admirably serves its purpose at sea in securing food. The fish is so thin that it swims very slowly, but being inconspicuous when seen head on it can readily approach its prey. It advances in a lopsided fashion upon its unsuspecting prey — small sprats, gobies, sand eels and so forth. When near, it suddenly shoots out its telescopic mouth and makes its grab — so neatly that the companions of the victim are not alarmed, but remain to be captured in turn when the first has been swallowed.

The mackerel introduces us to another series of related groups, of which the mackerel itself is commercially the most important. The true mackerel is one of the most perfectly adapted of fish. Mackerels have enormous muscular development, and the muscles, to compensate for the almost continuous and violent exertion to which they are submitted, are abnormally supplied with blood vessels. The protective coloration is perfect, for the dark striping above blends with the dark ocean floor and deeper water, and the white underside blends with the lighter water near the surface. Their wide range of food is admirable for the maintenance in health and vigor of an enormous number of the genus. They spawn at sea, but during their migrations flee landwards in quest of herrings and their young, which at such a season constitute their normal diet. Lacking this, they flourish on the inexhaustible minute, floating crustaceans with which the sea is crowded. The mackerel in turn fall prey to sharks, cod, porpoises and whales.

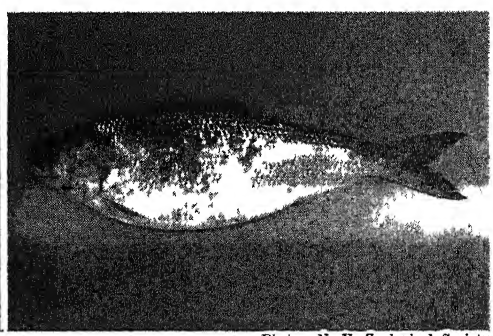
The tunnies, which are included in our present group (the mackerels), comprise some very fine fish, reaching a length of over ten feet and a weight of half a ton. The tunny is shaped like a mackerel but it is more robust and has a more slender tail. It has been an extremely important food fish in Mediterranean countries for many centuries; the ancient Greeks and Romans considered certain parts of the flesh particularly delicious. A near relative, the bonito — a deadly enemy of the flying fish — is a smaller fish, rarely more than a yard in length. The albacore, another close relative, which is commonly found in company with the bonito, is twice the size of the latter fish.

In considering large pelagic (living in or on the open sea) fish, the tarpon may be mentioned. It is somewhat salmon-shaped and is a powerful swimer and leaper, making leaps eight or nine feet above the water. It is often six or seven feet long and may weigh well over a hundred pounds. Its flesh is not prized, but it offers great sport for fishing with rod and line.

The flatfish are a freakish family. When hatched they are all perfectly symmetrical, shaped like other fishes. But ages ago, when their ancestors first took to ground feeding, the shape was found inconvenient. It was necessary to remain



Mullet, valued food fish, measure up to two feet.



Photos, N. Y. Zoological Society

Shad, kin to the herring, ascend rivers to spawn.

long upon the ooze to secure full measure of food, and the weary fish canted a little to one side to secure greater support than was obtainable by contact merely between its ventral surface and the ground And today, at a certain stage in the early infancy of the flat-fish, there comes a renewal of that canting over. The body leans towards the left. Back and belly cease to be uppermost and lowermost; the left side becomes to all appearance the ventral side, the right side the back. But that necessitates a change in the character of the head. That, too, must be flat, and flattened it becomes. That leaves the left eye in a difficult position, and that organ, conforming to altered conditions, travels round from the left side of the head to the right side, though in certain species this progress of the eyes is reversed.

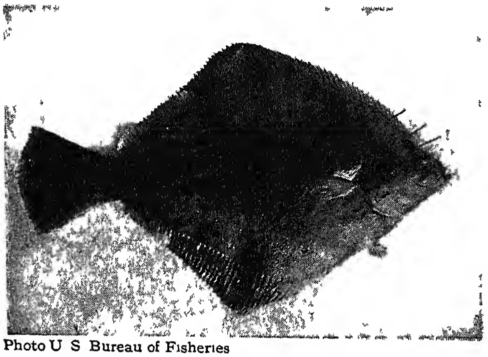


Photo U S Bureau of Fisheries

THE FLOUNDER

And whether it be sole or flounder, halibut or turbot, every flat-fish that comes to table has undergone this extraordinary metamorphosis. The fins which we discover along the "sides", as we call them, are really the vestiges of back and belly; the under part of the fish is simply its left side, the upper part its right.

Thus shaped, the flat-fish can feed resting upon the sea-bottom. It desires no more active life. It travels, unless carried by the tide, a mile an hour, and no more. Another point to be noted is as to coloration. The larvæ are colored on both sides alike. When the change of outline comes about, however, the left side, which becomes the lower, resting upon the muddy bed of the sea, loses its coloration. which is restricted to the right or upper side. This might pass unnoted were it not for the more remarkable fact that the scheme of protective coloration may be seen by experiment in actual operation A flat-fish which has passed through all the necessary transformations, and fixed the tone of its unpigmented under side, can be caused to revert, as to this under side, to the coloration to which it was hatched. Such a fish, placed in an aquarium, with light reflected from below, gradually adopts a pigmented left side precisely matching the tone of its right

Nature performs the miracle for the flat-fish; the latter have little enough to do for themselves. They lie for the most part quiescent, buried in mud or sand, with their elevated eyes raised just clear of impediments, enabling them to detect the proximity of potential food. The king of them all, in point of size, is the halibut, which attains a length of 7 feet or more and very great weight.

The turbot, an extremely prolific as well as a weighty fish, is declared by the gourmet to be by far the best food-fish of its tribe. It attains a yard in length, and, feeding entirely upon other fish and crustaceans, resembles the angler-fish in its habit of burying itself from the view of its victims. The turbot is found in both American and European waters, and the brill, a smaller fish of the same family, is a common article of diet in England.

The plaice and flounder are alike in that the jaw and teeth are much more developed on the left or lower side than on the other. Plaice find their food-staples among razor-shells — the muscular foot of which is eaten — lugworms, cockles, etc. The plaice keeps well to sea, but the flounder ascends brackish waters, except at spawning time, when it fares forth into deeper water that it may safely deposit the eggs. The sole diets itself chiefly on worms, which it traces by sight, smell and touch. The latter sense is aided by the presence of delicate tactile filaments on the side of the head. Trebly armed in this manner for the chase, the sole relies less than the others of its tribe upon vision, and eyesight is decidedly not its strong point.

The bulk of the flat-fish hug the shore, but some of the larger find safety and an ample food supply 600 feet deep Whatever their normal station, they with one accord put out to sea when about to spawn. They deposit their ova upon the surface of the sea, and various interesting devices are noted as to the manner in which the eggs are kept afloat, some by their own buoyancy, some by capsules of oil which maintain each egg in a certain position, some again in an oily envelope which merely secures a floating position, no matter what part be uppermost.

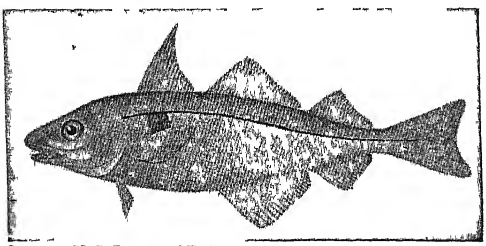
This retreat from the shore at spawning time has engaged the attention of more than one biologist, and various attempts at a solution have been made. One suggestion was that the increased pressure of a greater depth of water assisted the female in the extrusion of the eggs. That, however, cannot be substantiated. Of other explanations the most feasible is the simplest, albeit it implies another high tribute to the teaching by nature of her humble children. The inshore waters are crowded with multitudinous life. Deposited in such surroundings, the ova would, for the most part, be devoured. In the struggle for existence the flat-fish have produced species and genera which have acquired the habit of going out to sea to spawn The progeny of those which early formed the habit of doing so have survived, and the instinct is born in each generation to weigh anchor and betake themselves to the deeps when the spring is at hand Cast upon the surface of the sea, the ova mature and hatch before the tides have carried them back to the danger-zone in the vicinity of the coast The larvæ, when hatched, are very active, and are able at once, if not all to escape their enemies, at least to make so bold a bid for safety that a large percentage live to carry on eventually, in turn, the providential habit of seeking secure nurseries in the open sea

Courtesy N Y Zoological Society Photo Elwin R Sanborn

THE COD, SHOWING THE THREE DORSAL FINS AND CHIN BARBEL

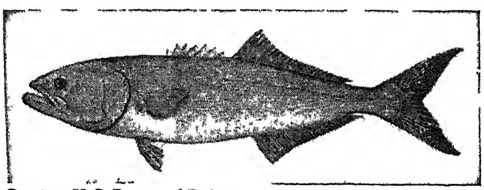
One of the best known groups of marine fishes so far as food supply is concerned is that of the cods which, in addition to the common codfish, include the frostfish, pollock and haddock. The body is long, tapering toward the tail. Among distinguishing features they possess three distinct dorsal fins and a slender barbel projecting downward under the chin. Both America and Europe have a freshwater representative of this group. In America it is variously known as the burbot, ling, fresh-water cod or lawyer. It is found from New England through the Great Lakes region and as far west as the Yukon River in Alaska.

The salt-water cod, commonly called a "codfish" (the "codfish" of the San Francisco markets is an entirely different fish, a chirid), is found everywhere along the North Atlantic coasts. They average about 15 pounds in weight, though exceptionally large and heavy specimens are common. The usual habitat of the cod is on ocean banks where the water is from 150 to 300 feet in depth and where they feed close to the bottom; but they frequently enter fresh-water rivers and apparently remain for considerable periods.



Courtesy U S Bureau of Fisheries
THE HADDOCK

The cod is a voracious feeder, eating all manner of small fishes, and quantities of deep-sea clams, which it swallows whole. The most common method of taking the cod is by hook and line as practised extensively on the banks of Newfoundland. In the North Sea, however, they are taken by deep-sea trawlers, especially at spawning time, during which they do not feed.



Courtesy U S Bureau of Fisheries
THE BLUEFISH

The breeding habits of the cod are somewhat out of the ordinary. In one respect they resemble the salmon in that they spawn from September to November when the temperature is falling. They make no special migration toward shore but deposit their eggs wherever they happen to be, leaving them to float to the surface. A large cod may deposit as many as 9,000,000 eggs in a single season. The liver of the cod yields large quantities of oil used in medicinal emulsions.

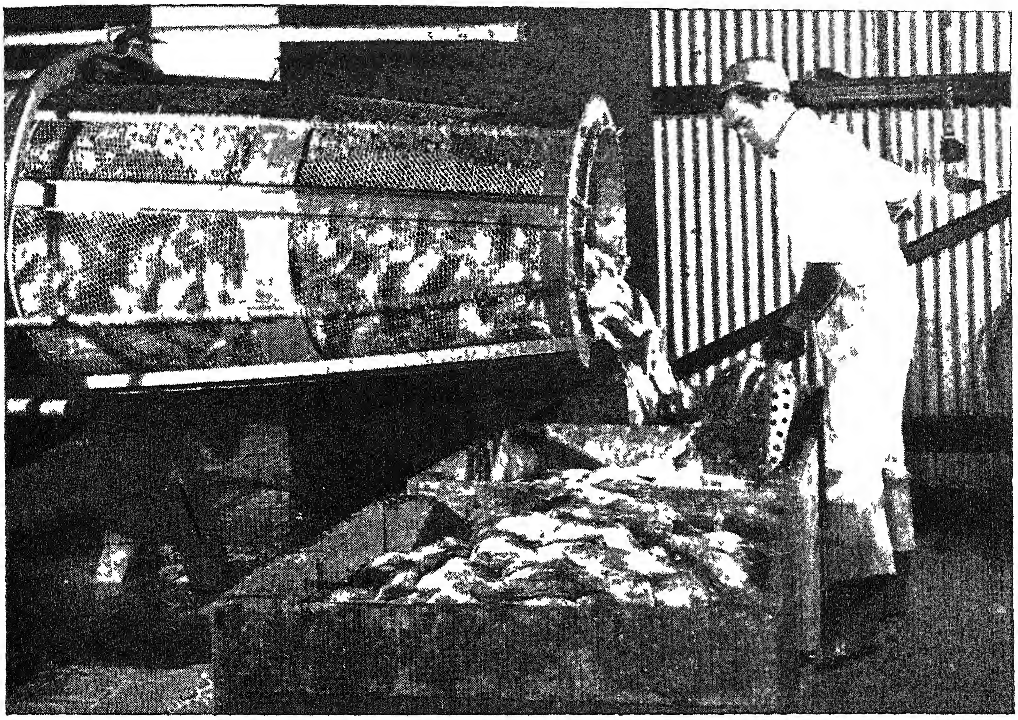
The haddock is the nearest relative of the cod; and though smaller examples are the more common, some well-favored specimens measure well over three feet in length Associating in large shoals, these fish approach the coast when about to spawn An ordinary female will produce over a million eggs annually. In stormy weather the haddock retire to deep water in which seaweed abounds. Here they are doubly protected — against the violence of the waves and against the wiles of the fisherman They are off-shore fish, and quite tiny fry are to be found in water 180 feet deep. They realize that danger lurks in shallow water. Aside from finding a ready market fresh, they are successfully smoked after the Scotch manner of "finnan haddie" (haddock cured at Findon).

One of the most popular members of the cod tribe is undoubtedly the whiting — popular, that is, with the epicure. Its weight varies between $1\frac{1}{4}$ and 4 pounds, though, of course, still larger specimens are at times brought to market. This fish preys upon the larvæ of other fish, and, like the rest of carnivorous fishes, is a pronounced cannibal. Although young cod and young whiting are hardly distinguishable by even the expert naturalist, the children of the seas make no mistake. In proof of this we may mention that there is one special parasite for the whiting and another for the cod.

In the New England markets the blue fish is highly prized as an article of diet and occasionally one sees a swordfish on the fishmonger's tables. Our coastal waters also furnish a number of representatives of the mullet family. Many of the fishes that have been discussed are not peculiar to American waters but most of them are represented in European waters as well. Thus we find the gray mullet of the English waters more important as a sea food than the species peculiar to our waters, and the wrasse, while little known to us, is an important food fish in England.

Neither the abundance nor the fertility of fish should lead us to overlook the need for the scientific conservation and propagation of this source of food and valuable by-products.

PREPARATION OF FISH FOR QUICK-FREEZING



The fish pouring out of this revolving steel drum have just been scaled and washed by machinery.

Both photos, Birds Eye Frosted Foods

Skilled operators now fillet the fish, carefully separating the firm meat from the skin and bones.

COMPLETING THE QUICK-FREEZING PROCESS

Candling: strong lights set under the work tables reveal bits of bone and skin, which are snipped out

Both photos, Birds Eye Frosted Foods

When the fillets have been carefully cleaned, wrapped and packaged, they are ready for quick-freezing

A COSMIC BOMBARDMENT

How Billions of Meteors Rush Every Day into the Earth's Atmosphere and are Destroyed by Friction

THE CELESTIAL MESSENGERS' STORY

A GREAT shower of shooting stars, which is a magnificent spectacle, is of rare occurrence, but anyone who watches the heavens on a clear, moonless night may see in an hour's time many of these bright bodies appearing as swiftly moving points of light darting across the sky, and visible usually for somewhat less than a second. Besides these isolated examples, small showers, seen only by assiduous watchers, occur almost every night; but the chief displays of celestial pyrotechnics, including many thousands of shooting stars, and lasting throughout whole nights, occur at intervals with a regular periodicity

Sir Robert Ball, the astronomer, gives the following description of the extraordinary shower of fire on the night between November 13 and 14, 1866, which shows the impression that display made on him: "The night was fine, the moon absent. The meteors were distinguished not only by their enormous multitude, but by their intrinsic magnificence. I was engaged in my usual duty of observing nebulæ with Lord Rosse's great reflecting telescope I was, of course, aware that a shower of meteors had been predicted, but nothing that I had heard prepared me for the splendid spectacle so soon to be unfolded. It was about ten o'clock when an exclamation from an attendant by my side made me look up from the telescope, just in time to see a fine meteor dash across the sky. It was presently followed by another, and then again by others in twos and threes, which showed that the prediction of a great shower was likely to be verified. . . . For the next two or three hours we witnessed a spectacle which can never fade from my memory The shooting stars gradually increased in number, until sometimes several were seen at once. Sometimes they swept over our heads, sometimes to the right, sometimes to the left, but they all diverged from the east. As the night wore on the constellation Leo ascended above the horizon, and then the remarkable character of the shower was disclosed. All the tracks of the meteors radiated from Leo. Sometimes a meteor appeared to come almost directly towards us, and then its path was so foreshortened that it had hardly any appreciable length, and looked like an ordinary fixed star swelling into brilliancy and then as rapidly vanishing. Occasionally luminous trains would linger on for many minutes after the meteor had flashed across, but the great majority of the trains in this shower were evanescent. It would be impossible to say how many thousands of meteors were seen, each one of which was bright enough to have elicited a note of admiration on any ordinary night." Such were the showers chronicled in olden times as heavenly portents, and recognized by modern astronomers as recurring with wonderful regularity.

In addition to knowing the exact dates when meteor showers may be seen, we know also that in the case of sporadic or occasional meteors many more may be seen after midnight than before. The observer at that time is on the front of the earth as it advances in its orbit, and is rushing to meet the meteors. Many more meteors fall during the latter half of the year than are visible in the earlier half.

Meteors are particularly interesting to us because they are the only heavenly bodies which we can touch and examine otherwise than by the analysis of light. We can actually saw pieces off a meteoric fragment and subject it to various kinds of tests in the laboratory. They are interesting also because they are probably left-overs from the formation of the solar system. Meteors, which are sometimes called shooting stars, are dark bodies usually of iron or stone. The usual velocity of meteors is about 25 miles a second, but they enter our atmosphere at very different speeds. For the earth itself is moving at a speed of somewhat over 18 miles a second, and consequently, if the meteor is traveling in the opposite direction to the earth so as to meet us, its apparent velocity may be more than 43 miles a second; but if it is overtaking us, its velocity relative to the earth may be not more than 8 or 10 miles a second.

But this initial velocity relative to the earth, whether greater or less, is quickly retarded by the resistance and friction of the atmosphere into which the meteor has plunged; and the brilliant light, which is all that we usually see of the shooting star, is caused by the incandescence of its materials through the great heat evolved by that friction.

The velocity of meteors and the heat generated by them

It is calculated that the average velocity of a meteor on entering the earth's atmosphere is about a hundred times that of a rifle bullet, and that the latter velocity is sufficient to heat the bullet by 10° F. in the course of its flight. Inasmuch as the heating power of the atmospheric friction is proportional to the square of the velocity of the flying object, the flight of a shooting star is swift enough to produce ten thousand times the amount of heat generated by that of a rifle bullet.

Such an enormous development of heat is of course many times more than sufficient to light up a small meteor, converting it first into a shooting star, and then swiftly dissipating its materials in the form of fine dust And since the amount of light produced depends upon the mass and the velocity of the shooting star, it is certain that the mass of most of these bright evanescent objects is extremely small, perhaps hardly amounting to a grain in weight, for otherwise the light would be greater than it generally is. Occasionally, however, the masses which enter the atmosphere of the earth are so large as to survive the great heat developed by their journey through it, and they fall to the ground in solid form. Some of these greater meteors, when the fragments into which they have been broken by the fall have been fitted together, have been found to weigh hundreds of pounds. These great projectiles are, however, quite exceptional among meteors.

It has recently been estimated that many billions of these meteoric bodies enter the earth's atmosphere every twenty-four hours. Most of these, however, are so very small that they are not easily visible to the human eye.

How far away does a meteor's blaze become visible?

The above calculation is based upon the comparatively small number observed from any one point on the earth's surface throughout a clear, moonless night. But if those shooting stars were also included which are too small to be seen without a telescope, the estimated number would have to be increased twenty-fold. The astronomer who watches the skies with a large telescope sees meteors darting across the field of his vision with great frequency.

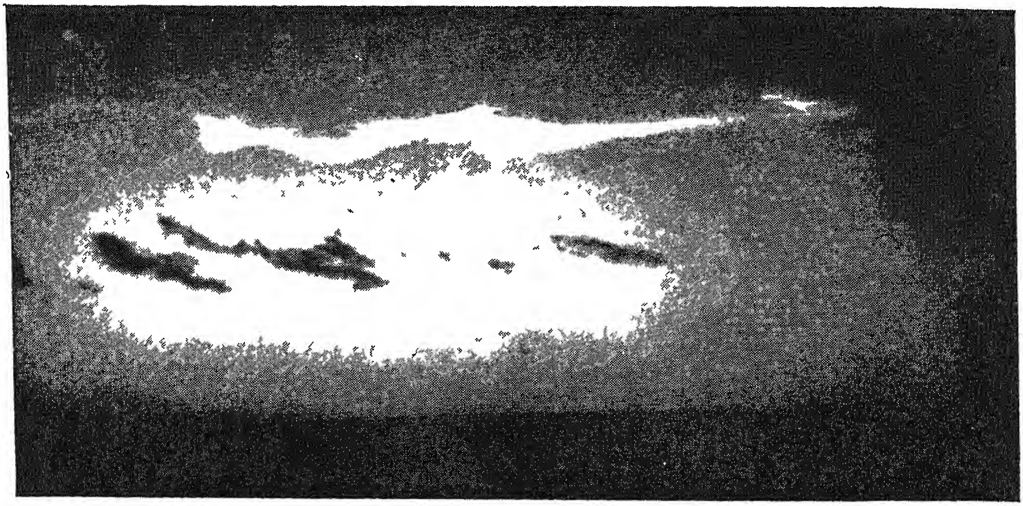
Exceptionally brilliant meteors, known as "fireballs", when entering the atmosphere at the swiftest speed, become incandescent, and therefore visible, at a height of about 80 or 100 miles above the earth's surface; those which are moving more slowly relatively to the earth begin to blaze at a height of about 50 miles; and ordinary shooting stars shine first at an elevation of about 62 miles. In the vast majority of cases the career of brilliancy is brief; most meteors cease to be visible at a height of about 40 or 50 miles above the surface of the earth, though some fireballs are seen as far down as 5 or 10 miles.

A VISITOR FROM OUTER SPACE

American Museum of Natural History

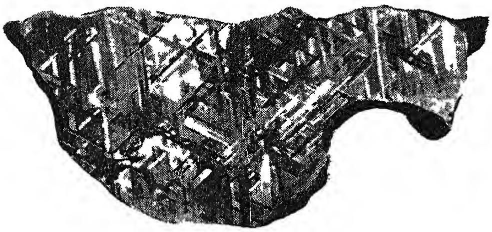
A brilliant fireball lighting up the night sky. From a well-known painting by Benson B. Moore.

METEORITES LARGE AND SMALL



Harvey H Nininger

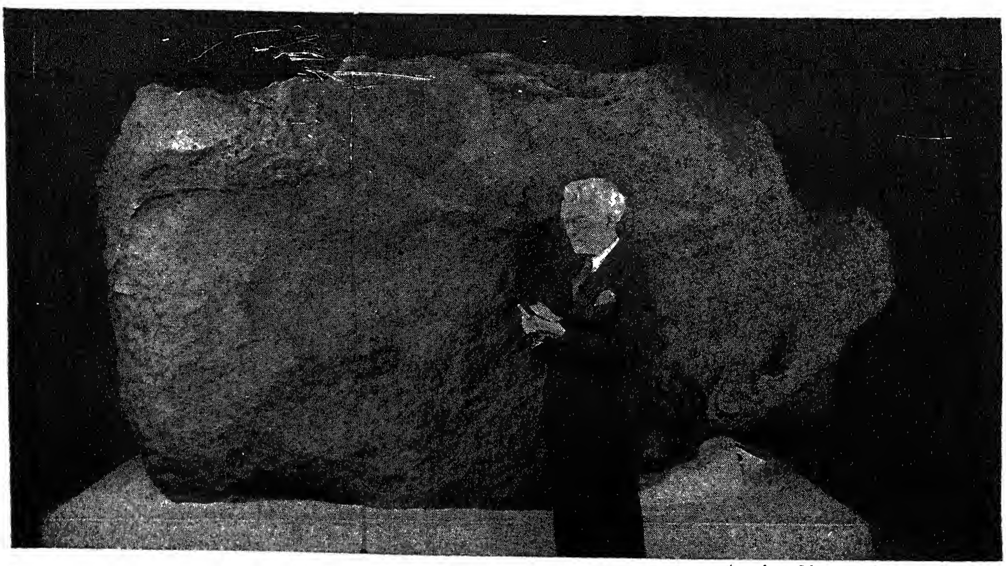
The white streak in this picture is the dust cloud produced by the famous meteorite of March 24, 1933



Pattern displayed by a nickel-iron meteorite when it has been polished and etched with weak acid

Both photos, Harvey H Nininger

These meteors, found far apart, fit together because they were once parts of the same meteor.



American Museum of Natural History

The 35-ton Ahnigito meteorite, in New York's Hayden Planetarium. It is the largest in any collection.

The length of the path traveled by a meteor during the period of its shining depends to a considerable extent on the angle at which it falls, and may be anything from forty miles up to many hundreds of miles.

Shooting stars may usually be traced throughout a space of 40 or 50 miles; but fireballs, especially when of the slower velocities, and when seen near the horizon, almost always traverse a path of over 100 miles in length.

The illusion as to the size of meteors because of luminous air

Some meteors, and especially the rarest and most resplendent fireballs, look very much larger than they really are. Indeed, their diameters sometimes appear to be as large as that of the moon, from which we should naturally judge that they had a real diameter of several hundred feet. But this is all an illusion which is easily accounted for. Actually, some very bright meteors, when they enter the atmosphere, do not weigh more than, say, 1000 or at most a few thousand pounds, nor in all probability do their diameters extend to 10 feet at the most. The largest single mass which has been seen to fall to earth — in Hungary, in the year 1866 — weighed less than 600 pounds, though a number of much larger meteorites have been discovered after their fall; thus at least four found in North America have individual masses of 10 tons or more and the largest one brought back from Greenland by Peary weighs 73,000 pounds. Many bright meteors are probably not larger than a grain of sand. The great amount of light produced is due partly to the glare of the momentary combustion, and partly to the fact that they are surrounded, during combustion, by an envelop of hot air and smoke that becomes luminous, and so greatly exaggerates their apparent dimensions.

The meteorites that reach the earth's surface are of great interest, as being specimens of extra-terrestrial materials, which can be inspected and analyzed. A great number of these bodies have been found, many having been seen to fall, but by far the majority have been distinguished as meteorites because of their physical characters. Farrington, in his very complete "Catalogue of Meteorites of North America", states that of the 600 or more meteorites known in the world up to 1909, 247 had been found in North America · of these 161 are classified as iron meteorites, 10 as iron-stone meteorites and the other 76 as stone meteorites. Out of the 171 members of the first two classes only four were actually seen to fall, while of the 76 stone meteorites 56 were seen to fall.

There are valuable collections of meteorites in the Yale, Amherst and Harvard museums; in the National Museum, Washington; the American Museum of Natural History, New York and the Field Museum of the University of Chicago.

The crust of meteors — how, and of what, it is formed

A characteristic mark of meteoric masses is the thin dark-colored crust or glazing, formed by the intense heating of their surface for the very short period of their passage through the air. This crust is usually not more than one-100th of an inch thick, due to the fact that the air through which the meteor rushes carries away the melted surface leaving only a very thin film of glazing.

This crust is actually a black glass containing many small bubbles; it consists largely of oxide of iron, and is highly magnetic. Occasionally there is also an inner layer of incompletely fused matter, containing particles of iron which have neither been melted nor oxidized. As a rule, the crust and the rest of the mass are clearly distinct from one another; they do not blend nor mingle, except where sometimes the glazing has apparently flowed through veins and fissures into the more or less crystalline mass of the meteorite. The crust is often of unequal thickness in different parts of the same meteorite, and forms ridges as the result of a flowing movement in the melted material The forward part of the meteorite, which meets the pressure of the air with the greatest force, becomes the most readily and fully liquefied, and the molten glaze flows backward.

Another common peculiarity of the crust is the appearance of numerous small "thumb-marks" or depressions, sometimes all over the meteorite, and sometimes on certain portions of the surface only. These may be due to the action of the air in driving off small portions from the melted surface, or, as is more probable, to the varying effects of heat and air on the different materials forming the meteorite, the holes representing the burning out of certain more fusible substances during flight; but the cause has not been determined with absolute certainty.

The fallen masses, when found, present the appearance of broken fragments, being of irregular shape, and often having many angular points. The various fragments which were picked up from the meteorite that fell at Butsura, India, were fitted together, and formed one complete mass of regular form, except for one corner Most of the fragments were coated all over with the typical glaze, showing that the explosion which separated them took place early in the meteor's career through the atmosphere; in other fragments, however, the faces which fitted together were not crusted, so that these must have been split apart by a later explosion, when the velocity of the meteor, and consequently the production of heat, had been reduced.

By the time they reach the earth's surface, meteorites are found to be still hot, but not, as a rule, hot enough to char wood nor soft enough to receive any impression of the surface upon which they fall. Instances are on record, however, in which the mass was found to be still glowing hot on reaching the earth.

The number of fragments in which a meteorite falls to the ground varies greatly; sometimes the mass arrives intact, sometimes in thousands of little pieces, but it is usually broken into several parts.

Meteorites fall, of course, in complete independence of weather conditions or of any other terrestrial circumstance But the fall is often accompanied by violent detonations; and these, together with the brilliant flashing of the fireball, give to the phenomenon a general character not unlike that of the loudest thunder.

The fire and smoke which mark the path of the speeding meteor

The heat generated by the resistance of the atmosphere to a meteorite traveling with the initial velocity of 25 miles or more a second is many hundred times greater than that produced by the burning of an equal quantity of coal, and is far in excess of the heat required to melt the most refractory metals The heat and the pressure together are answerable for the explosions of the meteorites.

Long trails of luminous gas are often seen in the wake of a meteor. This is due to masses of molten matter swept away from the surface of the meteorite and turned to vapor by the heat of the surrounding air. Fresh layers of surface continue to be thus fused and swept away until the velocity of the meteorite has become retarded to about 2 miles a second, when the heat and the rush of air are no longer sufficient to melt and remove the material, and the fused surface cools and solidifies, forming the characteristic crust.

The sensations of onlookers witnessing meteoric falls

Very few of the big showers of shooting stars have been known to yield meteorites An exception was the Mazapil meteorite which fell in Mexico in 1885

The Thwing meteorite fell on the afternoon of a calm, hazy day, when there was no sign of thunder. A loud explosion was heard, followed by a hissing noise, and then by a shock as of some heavy body falling to the ground. The sounds were heard over a considerable area, and people ran to see what was the cause A plowman saw the meteorite fall not far from where he was standing It was found to have penetrated through the soil, and for several inches into the solid chalk beneath.

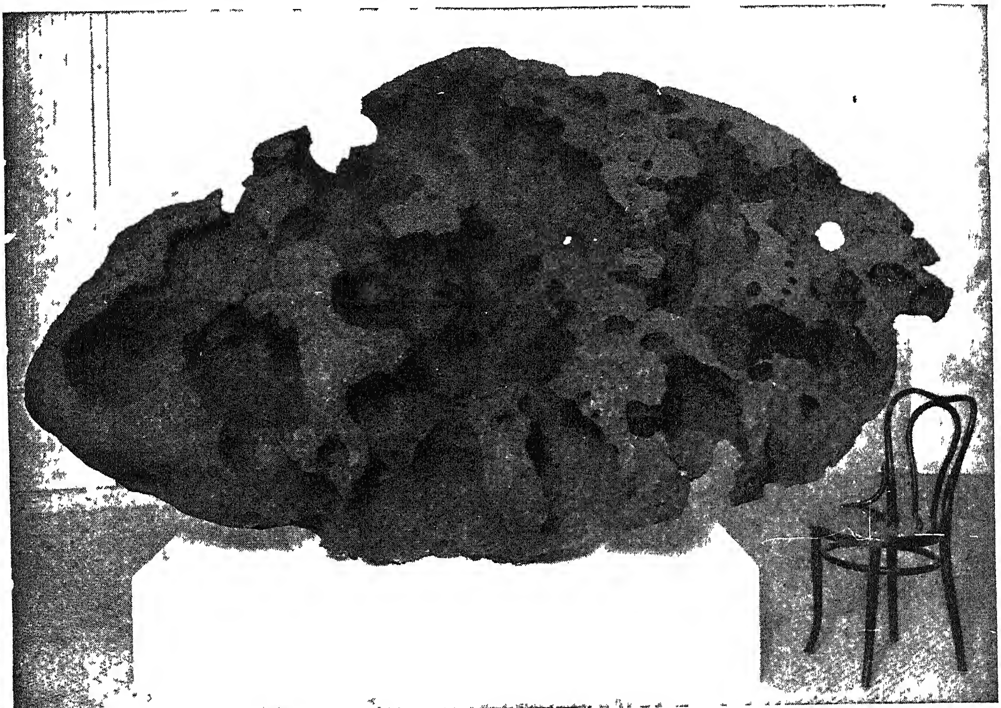
The Middlesbrough meteorite, which is of a low pyramidal shape, and measures 5 by 6 inches, with a height of 3 inches, fell during bright sunshine on a calm, clear day. Its fall was accompanied by a rushing or roaring sound overhead. Three minutes after its fall it was found to be slightly warm when drawn out of the

round, vertical hole it had made It is unusual for a meteorite to penetrate the earth in a vertical direction Most of the holes made by these bodies prove that the fall took place in an oblique direction

The oldest existing meteorite of the fall of which we have authentic record is still shown in the town hall at Ensisheim, in Alsace, where it fell on November 10, 1492 It weighed originally 260 pounds, and penetrated to a depth of 5 feet

Meteorites may be divided broadly into two classes, according as they are composed chiefly of stone (aerolites) or chiefly of iron (siderites), but between these two kinds there is a great variety of combinations of both. Sometimes the iron forms a sort of spongy framework within which stony masses are embedded; sometimes, on the contrary, the stone forms the basis, and larger or smaller masses of iron are disposed throughout it. Some authorities believe the aërolites to be of terrestrial origin and the siderites to be portions of disintegrated comets.

Meteoric iron is an alloy that is not represented among the mineral products of our earth; it consists of from 80 to 95 per cent of iron, combined with from 6 to 10 per cent of nickel The presence of nickel gives to meteoric iron a whitish appearance, and prevents the outer surfaces from rusting, as ordinary iron rusts. More than a dozen of the mineral constituents of meteorites have not been so far discovered among terrestrial minerals Meteoric stone, on the other hand, is composed of minerals which are found upon the earth, in lava and other volcanic products It is specially notable that carbon is occasionally present in the form of indistinctly crystallized diamond, in the famous Canyon Diabolo meteoric masses many small black diamonds have been found and in one piece there was discovered a tiny white diamond one-50th of an inch in diameter. Carbon is sometimes present also in the form of graphite. Many of the common mineral compounds of our earth are, however, entirely wanting in meteorites; for instance, quartz, the commonest of terrestrial minerals. No free quartz in any form has ever been found in a meteorite.



THE WILLAMETTE METEORITE FROM OREGON, SHOWING THE DEEP PITS FORMED BY OXIDATION

Though meteorites contain *minerals* not found on the earth, nevertheless the *chemical elements* of meteorites are all represented among our known chemical elements, and are almost all common among these. About one-third of the known terrestrial elements, including helium, have been found in these bodies. The most frequent, or most plentiful, are iron, nickel, magnesium, calcium, aluminum, carbon, oxygen, sulphur, silicon and phosphorus. Less frequent, or present in smaller quantities, are hydrogen, manganese, cobalt, copper, lithium, sodium, potassium, strontium, titanium, chromium, tin, chlorine, nitrogen, vanadium; and occasionally minute traces are found of gold, platinum, gallium and iridium. Some analysts have also reported the presence of arsenic, antimony, lead and a few other elements; but an exhaustive study of the chemical constitution of meteorites made by George P. Merrill, Head Curator of Geology, United States National Museum, makes the presence of these elements very doubtful. Iron occurs almost always, as we have said, in combination with nickel; phosphorus almost always in combination with both.

The extraordinary train of light which may be left by a fireball

No trace of organic matter of any kind has ever been discovered in meteorites; they bring us, therefore, no evidence of any living beings beyond our earth.

We have already seen that the fall of a meteorite is often accompanied by the appearance of a fireball, but many fireballs sweep across the sky without yielding, so far as we know, any meteoric fragments. A fireball is a shooting star of exceptional size and brilliancy, and is usually more or less pear-shaped. It appears with startling suddenness, and resembles a superb mass of liquid fire moving across the sky and falling earthwards in a sweeping curve. Not infrequently a fireball leaves behind it a train of ruddy sparks or a curved streak of light, and this luminous train often remains for some minutes, and has been observed as long as forty-five minutes after the passage of the meteor.

The origin of meteorites neither terrestrial nor atmospheric, but cosmical

Both the path of the fireball itself and the form of the trail which it leaves behind it show irregularities in their curves, due to the force of the currents of air. Some fireballs move as swiftly as ordinary shooting stars, but the finest ones move much more slowly; they radiate, as a rule, from near the horizon, and pursue a more or less horizontal path of a hundred miles or more in length before they disappear. A particularly resplendent fireball was seen during the star-shower of November, 1833, over Niagara Falls. It had the appearance of remaining for some time almost stationary high over the falls, giving off radiant streams of light in all directions. If a fireball falls in the daytime, the ball of fire and the train are seen only as white clouds, their brightness being invisible in the far greater brilliancy of sunlight.

As to the origin of meteorites, as distinct from aërolites, it is now fully established that they are cosmical and not terrestrial nor atmospheric phenomena. The idea of stones falling from heaven was hinted at from the earliest times, but was scorned by men of science until comparatively recent years. The ancient popular belief is shown by the veneration in which a number of such stones were held; of these the most noted example is the base on which was erected the statue of Diana of the Ephesians, tradition stating that this stone had fallen from the skies. It is now known that inconceivable multitudes of these bodies infest space; that they move in regular orbits round the sun in accordance with the law of gravitation; that they are invisible to us until they enter our atmosphere and become ignited by the friction due to their passage through it; that, having entered the terrestrial atmosphere, few, if any, can again escape from it, but fall towards the earth, and are reduced to imperceptible dust; and that some of the larger survive the passage and fall to the earth's surface, providing us with practical evidence as to the physical nature of bodies outside our planet.

The identity in composition of meteoric masses

There is no reason to suppose that there is any radical difference between the nature of the meteors which reach the earth's surface and that of any others, including the showers of shooting stars. All these phenomena present the same features, although none of the great showers has been known to result in the fall of meteorites to the ground, with the possible exception of the Mazapil meteorite above referred to. Inasmuch, therefore, as we are able to put together what we learn from meteorites with what we learn from the showers of shooting stars, meteors form a most valuable source of knowledge, especially, as we shall see in a later chapter, in connection with comets, for the close relation between comets and shooting stars is amply demonstrated by the history of some of the great showers and of certain comets.

Problems of the direction of meteoric flights solved and unsolved

At regular times, as we have seen, meteors appear in great numbers, many thousands of them within a few hours, darting in all directions across the sky. But when these directions of flight are carefully observed, it is found that all of them, with perhaps a very few exceptions, diverge from one point in the sky, known as the "radiant". All the lines of direction, if produced backward, meet in this point; and the position of this radiant among the fixed stars is the same from whatever place on the earth it is observed. It is evident, therefore, that there is no actual point from which the meteors do, in fact, diverge. The effect is due simply to perspective; the meteors move actually in parallel lines and the radiant represents the vanishing point. A line drawn from the radiant to the observer gives, therefore, the actual direction of these parallel lines.

The position of the radiant depends entirely upon the direction in which the meteors are moving relatively to the motion of the earth.

But the particles which constitute meteors are of extremely irregular form, and they are consequently apt to be deflected somewhat from their course when they enter the atmosphere; and, further, it is unlikely that they travel in precisely parallel lines. On this account the radiant is not actually a point but is a small area in the sky, which is seldom, however, as much as two degrees in diameter.

In the case of showers which last for days or weeks, the position of the radiant is found to move slowly among the stars night by night. This change is due to the change of direction in the earth's motion, and is exactly what we should expect, since the position of the radiant depends upon the combination of the direction of the earth's motion with that of the meteors. Some exceptions have, however, been observed. In some cases the radiant is found to maintain its position among the fixed stars, notably in the case of the showers known as "the Orionids". This shower lasts from October 10 to 24, and its radiant point remains stationary the whole of this time. No explanation of this and other exceptions to the general rule has yet been found.

The mapping out of the courses of the meteorites

The radiants of about a hundred different recurrent showers are now catalogued. The most important of these are: The Leonids, November 13–14; the Andromids, November 27; the Perseids, near the middle of August; the Draconids, January 2; the Lyrids, April 20; the Aquarids I., May 6; the Aquarids II., July 28; the Orionids, October 10–24. The names of these showers are of course derived from the situation of their respective radiants; for example, the Leonids all radiate from a point within the constellation Leo.

As early as 1811, some idea of a possible periodicity in the motions of meteors seems to have occurred to astronomers; and in 1833, when the fact of the radiant and its meaning were clearly recognized, Professors Olmsted and Twining, of Yale, showed that this regularity of movement

in a large swarm of meteoric bodies was evidence of their cosmical origin, and of their motion in regular orbits round the sun. It was Professor Hubert A. Newton, also of Yale who, just before the recurrence of the Leonid shower in 1866, completed very laborious researches which brought to light historical records of brilliant star-showers on sixteen occasions in October or November, the earliest on record being in the year 902. The dates are at intervals or multiples of thirty-three years, while the day of the year has moved along the calendar at the rate of one month in a thousand years. Part of this alteration in date is accounted for by the change in the calendar, the actual variation in the date of the shower being about one day in seventy years. This gradual change of date implies a gradual change in the position of the orbit of the meteors, for if this had remained constant, the shower would always have crossed the earth's orbit in exactly the same place.

It was possible to calculate which of the planets would be able to produce the perturbations necessary to cause this change of orbit, and so to provide data for the determination of the orbit itself. From the direction of the Leonids, given by their radiant, and from their periodicity, it was found that there were five possible orbits for them — one long ellipse which required the whole of the thirty-three years to traverse; two almost circular orbits, one a little longer and the other a little shorter than the earth's path; and two smaller ellipses contained within the orbit of the earth. The calculation of the perturbations required to produce the change in the orbit made it possible to decide that the great orbit of thirty-three years is the true one.

This having been determined, another very interesting fact emerged. The orbit of the Leonids does not intersect the paths of Jupiter or of Saturn, but it does intersect that of Uranus; and Le Verrier showed that in the year 126 Uranus was at this place of intersection just at the time when the swarm of meteors was there. It is believed that this encounter fixes the date at which the Leonids received their present determinate orbit.

JOURNEYINGS OF THE ICE

How the Glaciers, as Travelers and Burden Bearers, Engineers and Engravers, Tell the Story of the Past

GLACIAL CREEPINGS NOW AND LONG AGO

RIVERS of ice, like rivers of water, do a certain amount of carrying and carving. As a glacier crawls down from the mountains to the plains, it carries on its back a burden of boulders and stones and soil. All the way down it digs away at the hillside and brings down upon itself a load of rubble. Rain, avalanches and little landslips serve to increase the load, and ultimately there are two long stripes known as "lateral moraines" or ridges of débris, one to the right and one to the left. When two glaciers unite, their two contiguous lateral moraines unite, and take up a central position on the joint glacier, making what is called a "median moraine". Usually toward the end of a glacier the lateral and median moraines are no longer distinguishable, and the stones and débris are scattered broadcast. Attached to the under surface of a glacier there is also a certain amount of soil and stones, forming what is called the "ground moraine". When a glacier melts and retreats it deposits the collection of stones and soil that has accumulated at its end, and this deposit is known as a "terminal moraine", and shows where a glacier once was, long after it has melted away.

The amount of débris thus transported may be very large, for to such a leviathan as a glacier no rock is too heavy. The moraines may form ramparts as high as 80 or 100 feet, and individual blocks may measure thousands of cubic yards. In the Valley of Saas there is a boulder of serpentine 1000 cubic yards in bulk. The stone called the Pierre-à-Bot, measuring 40,000 cubic feet, weighs 3000 tons. It is some 50 feet long, 40 feet high, and 20 feet wide. Yet it must have been carried sixty or seventy miles, and in all probability crossed the Lake of Neuchâtel. The Pflugstein, near Zurich, 60 feet high, 72,000 cubic feet in volume, and 4500 tons in weight, must have come across Lake Zurich from the Alps of Glarus. Near Monthey, in the Lower Valais, there is a belt of granite boulders, which stretches for miles above the left bank of the Rhône, near its junction with the Lake of Geneva. These Blocks of Monthey must have come from the Valley of Ferret, thirty or forty miles away; and one of them, the Pierre des Marmottes, is 60 feet long, 30 high, and 33 wide, with a volume of about 55,000 cubic feet.

Among the many erratics found in New England some are worthy of note. Massachusetts claims one at Bedford, weighing 2300 tons and another at Fall River, 5400 tons; Connecticut boasts of one near Montville 65 feet long, 60 feet wide, and 55 feet high, nearly 10,000 tons in weight.

Quite apart from such prodigies, the amount of material borne by glaciers as moraines may be very large; and if the glacier has been alternately advancing in summer and retreating in winter, a terminal moraine may represent the deposit of many years. In some cases, there are several heaped-up terminal moraines, one behind the other, showing that the glacier has retreated or advanced intermittently. In North Italy terminal moraines are found which rise out of the plains of Piedmont as mountains 1500 or 2000 feet high.

The enormous thickness of the ground moraine in the Greenland glaciers

The ground moraine in the case of most mountain glaciers is quite inconsiderable, and little more than a smear of mud and a sprinkling of stones; but in the great polar glaciers the amount of detritus carried along as ground moraine may be immense In all the Greenland glaciers this moraine is 100 or 150 feet thick, consisting of clay, earth, stones and sometimes large boulders, scattered through the ice In the lowest 12 or 15 feet the whole glacier seems to be composed of black débris In the Spitzbergen glaciers the same condition obtains. When glaciers of this type diminish or disappear they leave their track covered with earth and stones resembling the "boulder clay" and glacial drift found in various parts of Europe and America. Round the Booming Glacier, in Spitzbergen, where it has shrunk from larger dimensions, there are some square miles of tough mud which, if dried, would exactly resemble boulder clay.

The tremendous pressure with which glaciers grind the hardest rocks

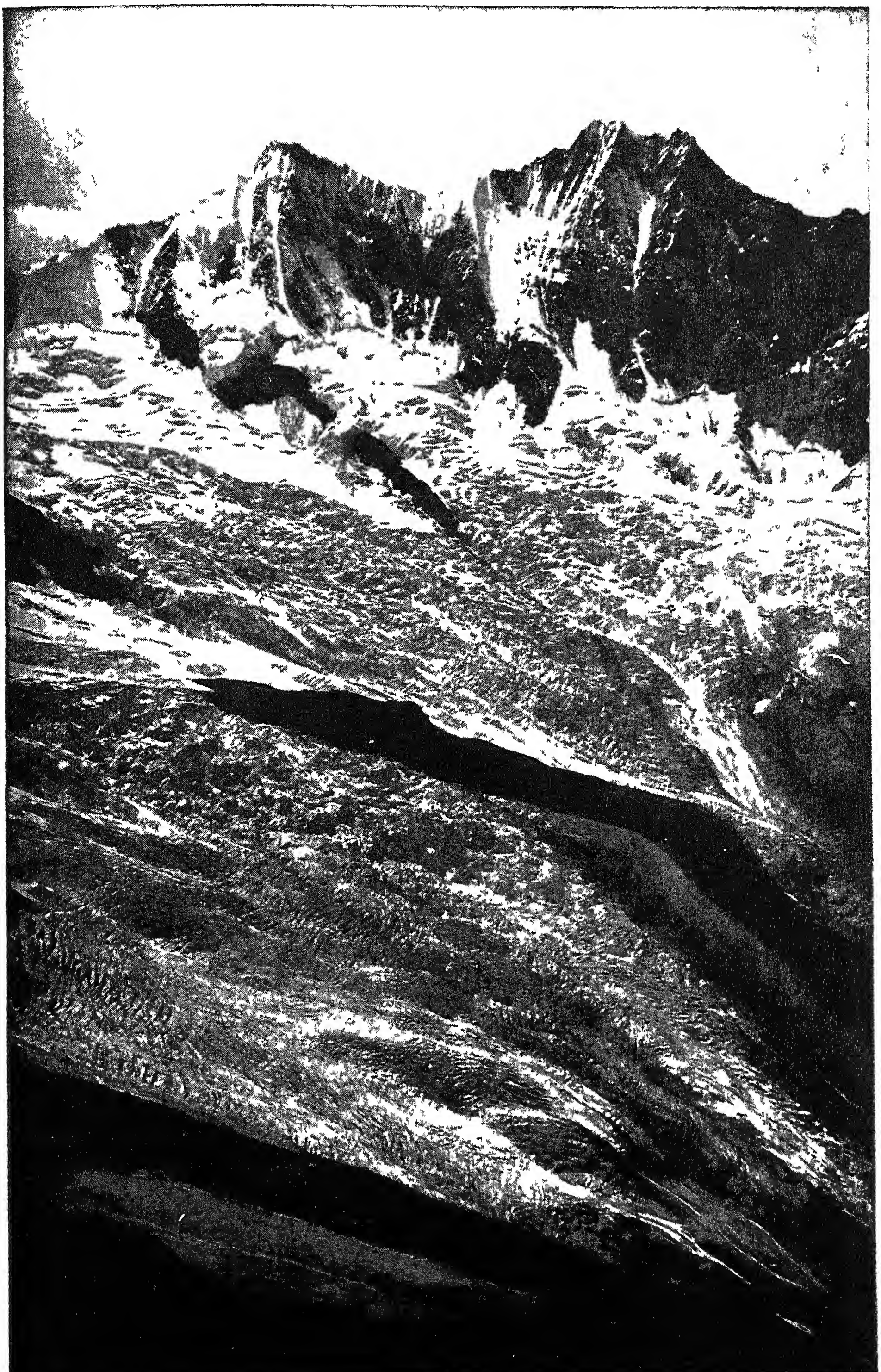
As we said, glaciers both carry and carve. Such enormous, weighty, moving Juggernauts must crush and grind as they move along, especially as they often, if not always, have sand and stones and rocks embedded in their lower surface. A glacier 1000 feet thick presses with a weight of over 500,000 pounds on every square yard of its bed; and though it may grind slowly, yet it grinds exceeding small. Even the hardest rocks are filed down and scored with scratches and ruts; and any collection of rocks which have been under the glacier present characteristic rounded forms like a flock of sheep lying-down, or the backs of plunging dolphins. Rocks ground by glaciers into such rounded forms are known as "roches moutonnées", since De Saussure, who first described them, compared them to well-dressed fleeces, or the wigs, styled in his day *moutonnées* Sometimes roches moutonnées are polished and smooth, but more often they are scratched.

The part glaciers play in remolding the surface of the earth

That glaciers can do so much is certain; and the only question is, how much more can they do? They can rub away rocks undoubtedly, but can they gouge out valleys? And are their valley-making efforts to be compared with the achievements of rivers? On this question there is a difference of opinion Some hold that such huge excavations as the beds of the Swiss lakes and of the Great Lakes were dug by glaciers; others consider them quite incapable of such big work On the whole, it is probable that they act rather as planes than as spades, and the deeper lake-beds and mountain valleys are not their work

Whatever work glaciers do effect, they are aided, to a great extent, by the streams that issue from and flow with them The water which flows from the lower end of a glacier is always muddy, and the mud represents a considerable amount of wear and tear, but wear and tear produced, perhaps, as much by the water as by the hard heel of the ice. Dr Albert Heim, the Swiss geologist, who has specialized on glacier study, calculates that the débris "removed annually by all the Justedal glaciers, in Norway, is equal to a cube of rock measuring 134½ feet on each side." And it has been calculated that during August the stream issuing from the Aar glacier carries away 280 tons of sand daily

The water that flows down through the crevasses of glaciers, and drills a hole or "moulin" through the ice to the underlying rock, often wears out the rock into gigantic potholes, known as "giants' kettles", and where these are found we may be sure a glacier has been. Near Lucerne several of these potholes were found in soft sandstone, some being several yards in depth and in circumference, and many of them are to be seen in Norway and northern Germany. Striking examples are also found in the hard rock on the shores of Lake George. A deep one having the appearance of a well may be seen in the sandstone on the brink of Ausable Chasm near Lake Champlain.

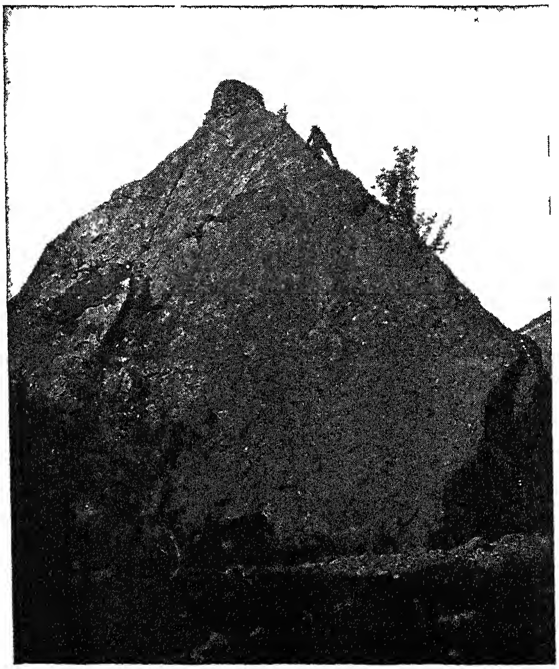


THE MAGNIFICENT FÉE GLACIER, AS VIEWED FROM THE EGGINER RIDGE, SWITZERLAND

The puzzling problem of the erratic boulders and its solution

Such, then, is the work of modern glaciers, but there have been times when glaciers have been much busier than now, and a record of their travels is to be found in many lands. At one time, indeed, glaciers seem to have spread over the greater part of the northern hemisphere.

This is generally recognized now, but it was not even suspected till quite modern times; and it was really the big erratic boulders we have already mentioned that gave the hint to geologists. For years the "erratics" had been a problem and puzzle. No one could say how they came to be distributed in such a strange fashion. No one could say how such massive boulders had been carried such great distances, often up hill and down dale



AN ERRATIC IN NORTHERN NORWAY

The unlearned, feeling that the boulders required some explanation, fell back upon the preternatural, and usually came to the conclusion that the devil had had a hand in it, and had been using the stones as quoits, or marbles. Such imaginative explanations, however, did not quite satisfy geologists, and they tried hard to find an adequate scientific explanation.

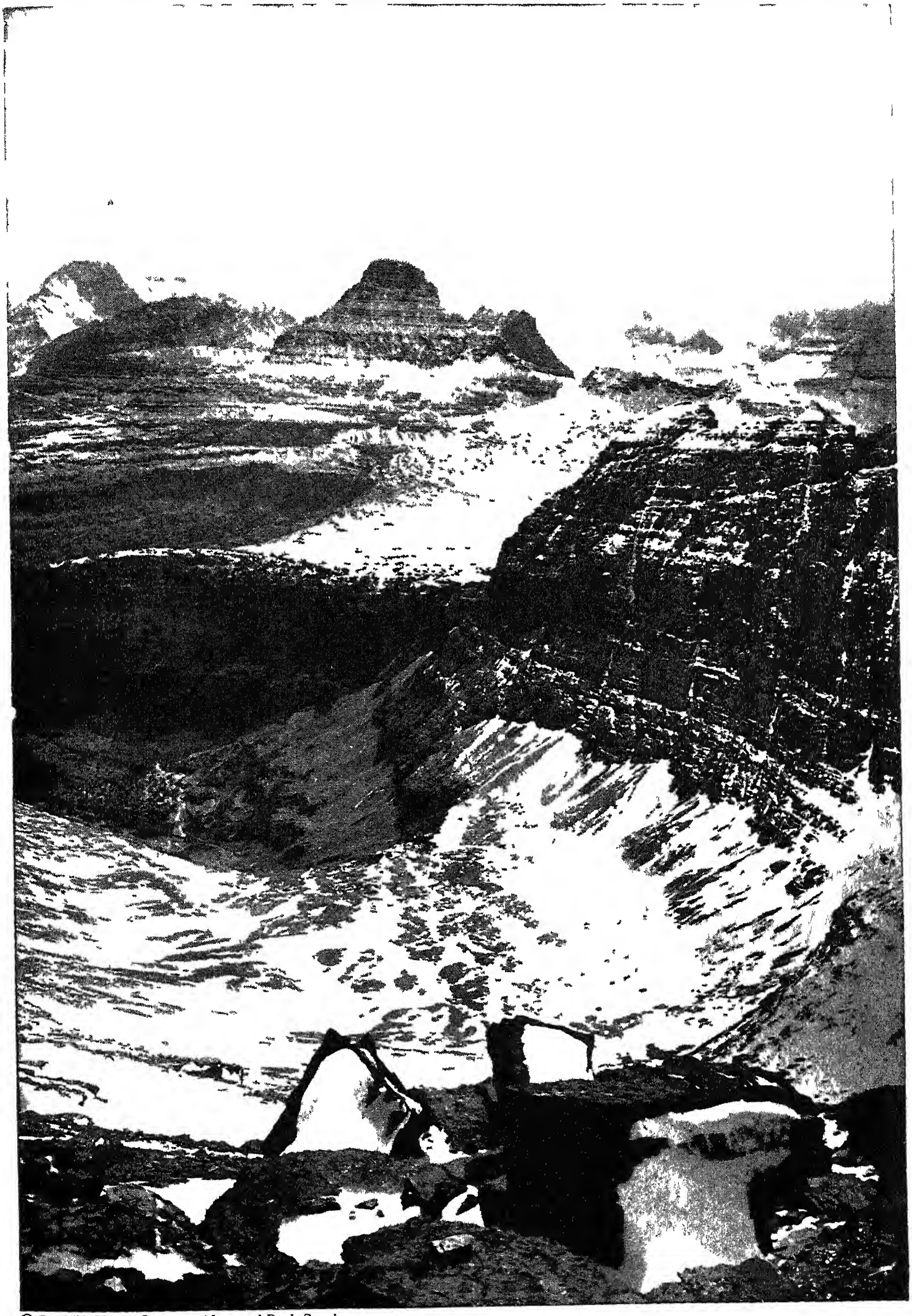
At first it was thought possible that great explosions or deluges had lifted and dispersed them. But explosions could hardly fling stones weighing 3000 tons a distance of 60 or 70 miles; nor could a deluge, however tremendous, carry a boulder up hill and down dale, over one hill into another valley, as erratics are often carried. Efforts to explain their transport by icebergs and floating ice were equally unsuccessful; and until the first decades of the last century no one thought of transport by glacier. Then the idea began to dawn upon men's minds, and this is how it happened.

In 1815, Jean de Charpentier, director of the mineral baths at Bex, spent a night in the cottage of a chamois-hunter; and in the course of a conversation about glaciers the latter stated that the glaciers "had formerly a much larger extent than at present Our whole valley was occupied by a vast glacier extending as far as Martigny, as is proved by the boulders found in the vicinity of this town, and which are far too large for the water to have carried them thither."

In 1829, a Swiss engineer named Venetz, who had been investigating the glaciers of the Swiss Alps, expressed his belief to De Charpentier that the whole Valais had been formerly the bed of an enormous glacier, more than 180 miles in length, and that this glacier had carried to the Jura blocks from the Alps.

The idea fell on good soil. De Charpentier thought over the mountaineer's and engineer's ideas, and finally communicated them as a scientific theory to a meeting of Swiss naturalists at Lucerne So bold and revolutionary was the theory that it met with great opposition. But a true theory will always find champions as well as enemies; and two young naturalists, Louis Agassiz and Carl Schimper, not only championed it, but developed out of it the greater theory of a Glacial Epoch. It was the logical outcome of the chamois-hunter's common sense.

SNOW-TOPPED PEAKS WHERE GLACIERS START



© Fred H. Kiser, Courtesy National Park Service

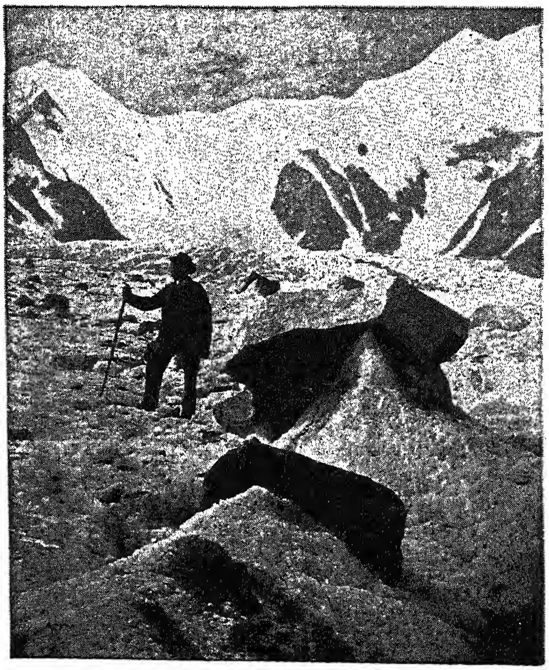
SOUTH FROM PIEGAN PASS, GLACIER NATIONAL PARK

If it required a glacier to carry the boulders to Martigny, it required glaciers to carry the boulders from the Alps to the Jura mountains, and to transport all the other erratics that were found in other localities.

Further, all over northern Europe and northern North America, ice had left its marks not only in erratic boulders, but in ruts and scratches and moraines, and roches moutonnées, and boulder clay, and "devils' punch-bowls". The more the matter was studied, the more certain it became that northern Europe and northern North America had once been under an ice-cap.

The evidence pointing to a glacial period is only circumstantial, but it is many-sided and absolutely conclusive.

Let us look, for instance, at the composition of boulder clay, or "till", as it is sometimes called. It consists of an exceedingly tough, tenacious clay, mixed with grit, pebbles, stones and rocks in varying amounts. The clay has evidently been subjected to great compression, and is so tough and compact that it is very difficult to excavate, and in some cases requires to be blasted out. The quantity and quality of the hard material in the clay vary considerably. Sometimes there are only a few stones sprinkled here and there; sometimes it is almost all stones. As a rule, there is more clay than stony material. The stones in the clay vary in size — they may be inches, or feet or yards in circumference. As a rule, they are from two to eight inches in diameter. Large or small are mixed higgledy-piggledy together. Now, it is obviously a very curious thing that stones of such varying sizes should be mixed up with clay in this way, like the raisins in a plum-pudding. How did it come about? Who stirred the pudding?



ROCKS TRAVELING ON A GLACIER

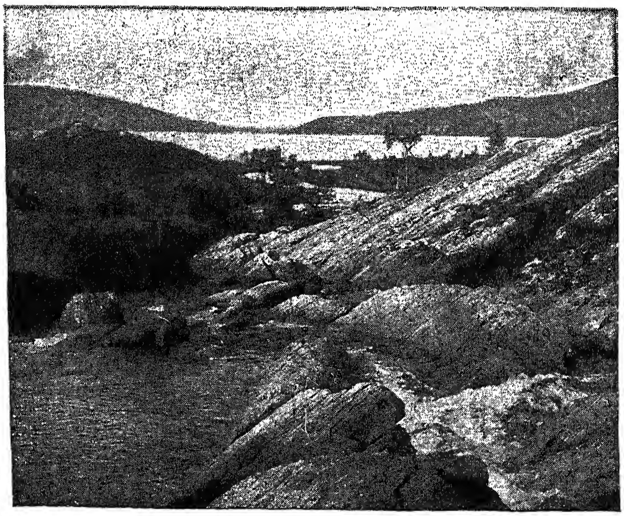
At one time it was thought to be the work of a deluge, and was even taken as a proof of the Flood. But a deluge would have sorted out the material, as the waves sort out the pebbles in the shingle of a beach; and not a single instance has even been known of boulder clay deposits after a deluge — after such a deluge, for instance, as was caused in Bengal by the Backerzunge cyclone. Neither running water nor tidal water, neither river nor sea, could have made the boulder clay mixture, but only the white pestles of the glaciers mashing up stones and mud in the mortars of the mountains and valleys.

Further, when we examine the stones and pebbles in the boulder clay, we find that they are not oval and round like stones and pebbles that have been rolled in rivers and on sea-beaches; they are rather flattened and angular, with rounded angles, and they are scratched, these scratches running usually parallel to their long axis. We do not find such scratches on stones which have been tossed and tumbled in rivers and oceans. On the contrary, these are polished and smooth; and we must regard the scratches as the authentic signature of glaciers. The stones, moreover, show no weathered crust; they show no signs of chemical erosion by water and air; they are quite sound and unoxidized, as if they had been just blasted from a quarry. All these facts point conclusively to glacial action.

CLIMBING THE GREAT GLACIER, GLACIER, BRITISH COLUMBIA

TERMINAL MORAINE AND STREAM FROM THE GREAT GLACIER
Photos Courtesy Canadian Pacific Railway

But we can go further still. If we clear the boulder clay off the underlying rocks, we find that the rocks are all scratched and grooved. Remarkable grooves in limestone are found on Kelley's Island in Lake Erie. They are neatly carved and have a fluted appearance. The striæ also depend on the nature of the rock containing them. Thus on the shores of Lake Champlain we find fine delicate lines in the compact limestone while, for example, in the exposures of the coarse Manhattan schist about New York, and notably in the Bronx Park, they are much rougher. What other tool save a glacier could have made such markings? Moreover wherever striated rocks are found, the scratches are from north or northeast to south or southwest, showing the direction of the glacier's flow. Besides we find that the marking instrument has managed to scratch not only the prominences and bulges of the rocks, but has marked the bottom of every dimple and depression. Again, what graving-tool save a glacier could have done it? The sea could not have done it; rain and wind and frost could not have done it. The work is undoubtedly the work of moving ice, whose polishing-powder contained both sand and rocks.



GLACIER-POLISHED ROCKS IN NORWAY

Again, in some places boulder clay is a thin layer; in other places it may be a hundred feet deep, and in some places it may be more than five hundred feet deep, but over any area covered with boulder clay the depth varies in an irregular way, quite independently of the nature and height of the ground. This irregularity of deposition is characteristic of a glacier, and could have been effected by no other natural agent. Yet, again, the rocks and stones mixed in the boulder clay are usually not all local: a certain percentage of the stones comes from a distance of some miles. Only a glacier could account for this mixture. Only glaciers could form the roches moutonnées, which are not in the least like rocks worn by rain and frost and rivers.

Finally, to make assurance doubly sure, we find in the boulder clay the shells of arctic seas. Towards the end of the Tertiary Epoch, the climate of the world seems gradually to have become cooler. During the greater part of that epoch the world was warmer than it is now, as is shown to us by the nature of its flora, which was sub-tropical, and its fauna, which included such animals as elephants, rhinoceroses, hippopotamuses, hyænas, saber-toothed tigers, apes. But towards its close the climate became much more severe, and we find that herds of reindeers wandered southwards as far as the Riviera and Switzerland, and that arctic shellfish found their way into European seas. Colder and colder grew the earth; further and further south came the ice, till England was a mass of glaciers, and an ice-sheet stretched between England and the Continent. Down from the mountains of Norway crept the ice and snow. Now Russia was buried under it, now northern Germany, now northern France. In Switzerland colossal glaciers filled the mountain valleys and flowed across the plains. The Rhône glacier invaded France, and from the southern side of the Alps huge glaciers descended upon Italy, leaving mighty moraines on the plains of Lombardy.

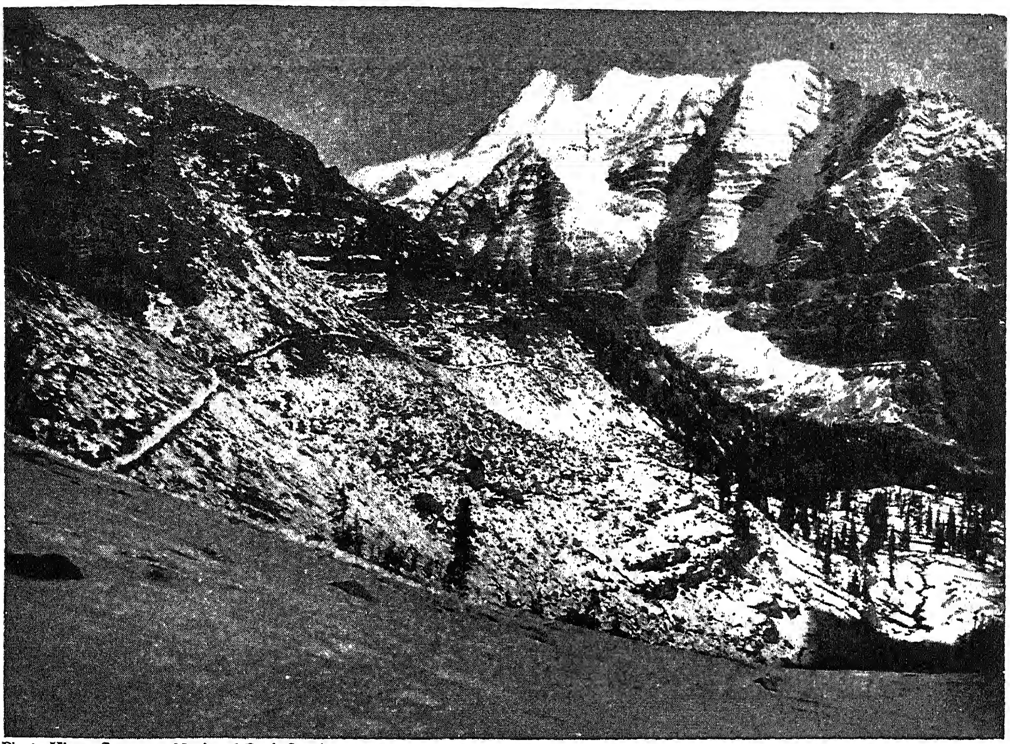
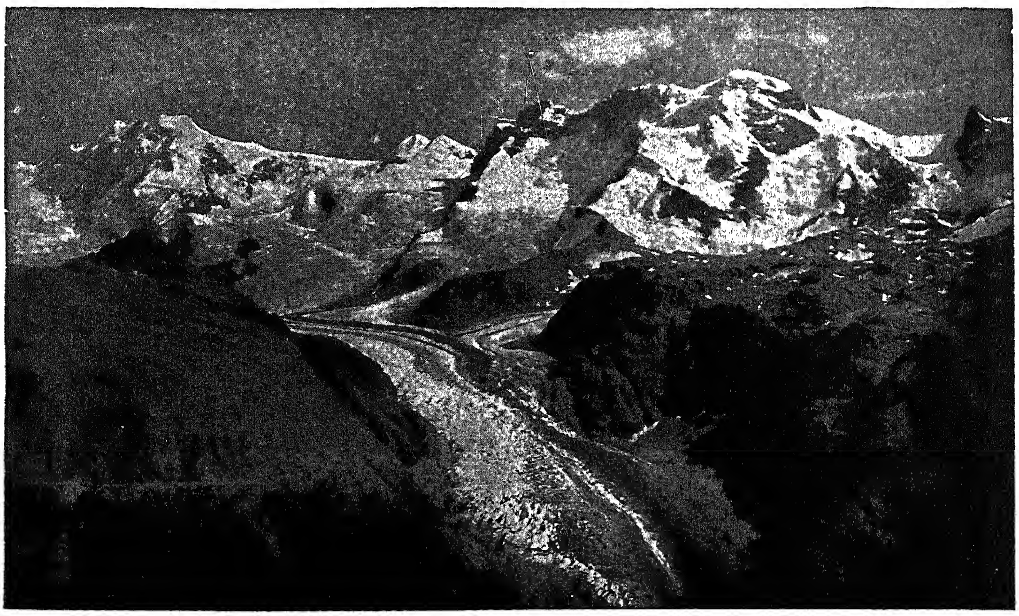


Photo Kiser, Courtesy National Park Service

THE ROCK-LADEN STREAM OF SNOW AND ICE. MOUNT JACKSON, GLACIER NATIONAL PARK



MEDIAN MORAINE AT THE JUNCTION OF THE GORNER, BREITHORN AND LYSKAMM GLACIERS

In America there were at least as many oscillations of heat and cold. During the whole glacial period there were various submergences and emergences of the land. When the ice invasion was most extensive, it is probable that the northern parts of Europe and of North America were much more elevated than now. Arctic shells that live at a depth of 30 to 90 feet have been found 1330 fathoms deep in the clay of the North Atlantic, which would seem indubitably to indicate that the northwest of Europe must have once stood about 7000 or 8000 feet higher than now, and that a tremendous subsidence took place in the northern hemisphere after the time of maximum glaciation.

From this subsidence the northern hemisphere never quite recovered, but marine shells found in Wales at a height of over 1200 feet, in the Scotch hills at a height of 500 feet, and in the valley of the Saskatchewan at a height of 1900 feet, show that reëmergence of the land did to some extent take place. The cause of the fall and rise is uncertain. Some attribute the submersion to the weight of the ice, and the emergence to the removal of the weight by the melting of the ice, but it is more likely that there were movements in the earth's crust quite apart from ice pressure.

In the caves of France and some other parts of Europe human bones and handmade implements have been found mingled with the bones of animals which were plentiful there during the glacial or interglacial periods. It is uncertain, however, whether man had reached America as early as the last glacial advance, for there is no evidence of human bones or implements among the remains of the extinct animals of American glacial times.

The cause of the Ice Age is unknown. Toward the end of the last century James Croll tried to show that it was due mainly to the indirect effects of an increased eccentricity of the earth's axis. With the sun farther away from the earth in winter, he thought that a colder and snowier winter would ensue in temperate latitudes, and that the winter snow would persist through the summer, and give rise to fogs which would intercept the summer sun. The trade winds and the ocean currents would consequently be altered, and the cumulative effect would be a genial epoch alternately in the northern and southern hemisphere. This theory did not stand the test of critical examination, and it is now almost completely given up by expert geologists.

Attempts have also been made by Chamberlin and Arrhenius to explain the glacial epoch on the basis of variations in the amount of carbon dioxide in the atmosphere. A little more or a little less carbon dioxide, by diminishing or increasing radiation of heat, would have important climatic consequences, but it is not certain that this alteration would be competent by itself to produce the glacial periods. Still a third attempt has been made to explain the Ice Age on the basis of geographical changes such as elevation of a vast area of land, with deflection of warm air and warm ocean currents. No doubt such geographical changes would produce climatic alterations, but the theory is still quite unproved. Altogether we must confess that no adequate scientific explanation of the Ice Age has yet been found.

It may be noted here that the great Ice Age of which we have been speaking is not a unique occurrence in the earth's history, for in the strata of earlier geological ages are found striæ, roches moutonnées and glacial boulders, giving clear evidence of the existence of a glacial epoch in the southern hemisphere during the Permian Period at the end of the remote Palæozoic Era.

THE GRIM WHITE PLAGUE*

The Story of Man's War against Tuberculosis

THERE was a time — only a brief generation or two ago — when tuberculosis was the most dreaded of all diseases. The white plague, as it was called, was terribly widespread. It was seldom detected until it had reached an advanced stage, too late to do anything about it. The patient would make his will and prepare for a long and agonizing last illness. If, by some lucky chance, he recovered, his friends would be convinced that he had not had tuberculosis at all.

Today the situation is not nearly so desperate, for tuberculosis can be detected at an early stage and it can be cured. Yet it is still a formidable menace to mankind. It kills more people than all other infectious diseases combined; it causes some five million deaths yearly throughout the world. It attacks the young, the middle-aged and the old. It represents a severe drain on the community, for vast sums of money must be spent annually to build and maintain hospitals, to care for patients and to provide pensions for those who have been made helpless by the disease.

Tuberculosis was known as far back as antiquity. Greek physicians called it "phthisis," which means wasting away; later the disease was given the alternate name of "consumption," from the Latin word *consumere,* which means to devour. Since wasting away of the body seemed to be the chief symptom of the disease, ancient physicians tried to combat it by building up the body through diet, change of climate and the regulation of exercise and rest. We now realize that this treatment was quite sensible. It was usually ineffective, however, since the diagnosis of consumption came too late for any form of treatment to do much good.

Throughout the centuries that followed, consumption continued to be as baffling as it was deadly. It was not until the nineteenth century that medical science began to solve the mystery of this dread disease.

In 1839 Dr. J. L. Schoenbein, a professor of medicine in Zurich, Switzerland, pointed out that little tubercles, or nodules, were often found on the bodies of persons who had died of consumption; he suggested, therefore, that the disease should be called tuberculosis. Neither Schoenbein nor the other medical men of his generation knew whether tuberculosis was a contagious disease — something introduced into the body from without — or a constitutional disease — something that arose spontaneously in the body or that was passed on from parents to children as an inheritance.

In the 1860's a French physician, Jean-Antoine Villemin (1827–92), demonstrated that it was possible to give tuberculosis to healthy animals by inoculating them with tuberculous material from infected human beings. At about the same time an English physician, William Budd (1811–80), also concluded that tuberculosis is a contagious disease; he outlined sound methods for preventing its spread. The next great advance was in 1882, when a German physician, Robert Koch (1843–1910), definitely isolated the tubercle bacillus, the germ that causes tuberculosis.

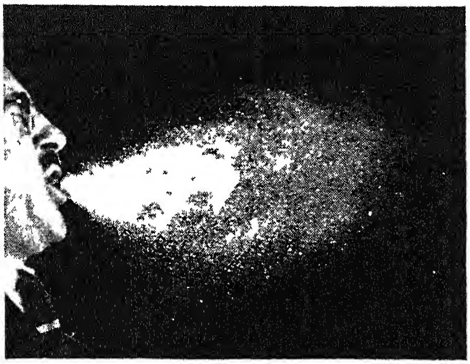
Thanks to these scientific pioneers, tuberculosis is no longer a mysterious ailment; we know that it is an infectious disease caused by the tubercle bacillus. It

* This abstract has been prepared, with the assistance of the National Tuberculosis Association, from *Tuberculosis, a Manual for Teachers,* published by the Council of the Tuberculosis and Health Associations of Greater New York.

is true that its growth in the human body may be due to a variety of factors — to lowered resistance, to poor diet, to unfavorable living and working conditions and so on. But, after all, where no tubercle bacilli are present, there can be no tuberculosis.

There are various types of tubercle bacilli; but only two kinds — bovine and human — are important from the human point of view.

Bovine tubercle bacilli are so called because they attack cattle; they also infect most other mammals, including man. They may produce pulmonary tuberculosis, or tuberculosis of the lungs, but generally attack the bones, joints and lymph nodes. Humans are infected by drinking raw milk from tuberculous cattle. Hence those who consume most milk — children under five years of age — are most frequently the victims of this type of bacillus.



In the United States effective measures have been taken to eliminate tuberculous cattle from dairy herds. Rigid laws have been passed, too, requiring the pasteurization of milk in cities and, in some cases, in entire states; this process kills the tubercle bacilli. As a result, bovine infection in man has become exceedingly rare in the United States. It is a different story in countries where pasteurization is not required and where little effort is made to remove diseased cows from dairy herds.

Human-type bacilli are responsible for the vast majority of cases of tuberculosis of the lung — by far the most prevalent form of the disease. These bacilli are microscopic, red-shaped bodies. Growing best at temperatures ranging from 96° F. to 100° F., they thrive in the human body; they can survive for long periods outside of the body.

The chief source of human-type tubercle bacilli are the body discharges of human beings sick with tuberculosis. Living bacilli are present in the sputum, or spit, of a patient with active tuberculosis of the lungs. Floor dust mixed with sputum may dry out and later may be raised into the air by air currents or through sweeping; these particles of dust will contain living tubercle bacilli. Bacilli are also to be found in the tiny droplets that are sprayed from the mouth and nose in coughing, sneezing and even in laughing or talking forcibly. In most cases of pulmonary tuberculosis, infection takes place when the bacilli contained in dust particles or droplets are inhaled. Bacilli may also be swallowed; such germs are responsible for infection in the lymph nodes of the neck, as well as in the intestines and other abdominal organs.

When a person coughs or sneezes, or even when he laughs or talks forcibly, he sprays the air with thousands of tiny droplets. These may contain tubercle bacilli, like those shown below. If a bystander inhales or swallows the bacilli, serious infection may result. Always hold a handkerchief in front of your mouth when you cough or sneeze.

National Tuberculosis Association

Lambert Pharmacal Company

Robert Koch bids his wife look through the microscope at the tubercle bacilli he has just isolated.

Fortunately for us, the human body has certain natural defenses against the invasion of the dangerous tubercle bacilli. The first line of defense is represented by the mucous membrane that lines body tubes and cavities that communicate with the outside. The mucous membrane of the respiratory tract is normally covered by a mucous "blanket," which is continually kept in motion through the action of cilia — tiny, hairlike structures. The direction of the motion is toward the pharynx, or throat — that is, away from the tubes leading to the lungs. Any stray bacteria that are inhaled are generally caught on the sticky mucous surface and are wafted to the throat. Here they are either coughed out or swallowed. If they are swallowed they are ordinarily flushed along, like silt in a stream, without being able to lodge anywhere, until they are destroyed by the strongly acid digestive juices or else eliminated from the body.

Suppose that certain bacilli get by the outer defenses of the body and lodge in the blood and lymph streams and eventually in the tissues. They are now confronted by a powerful inner line of defense. This is the army of phagocytes — specialized white cells that swallow any bacteria introduced into the body. If the invasion of bacilli can be confined to a small walled-off area, the body as a whole saves itself from tuberculous infection.

The body has still another protection against invading bacilli: the production of antibodies. When a given germ — call it A — is taken into the body, it often gives rise to an antibody, which we may call A′. A′ will unite with A and will counteract its effects. A different sort of germ — call it B — will produce a different kind of antibody — B′. The antibodies brought into being by tubercle bacilli may be effective enough to neutralize completely the effect of these bacilli.

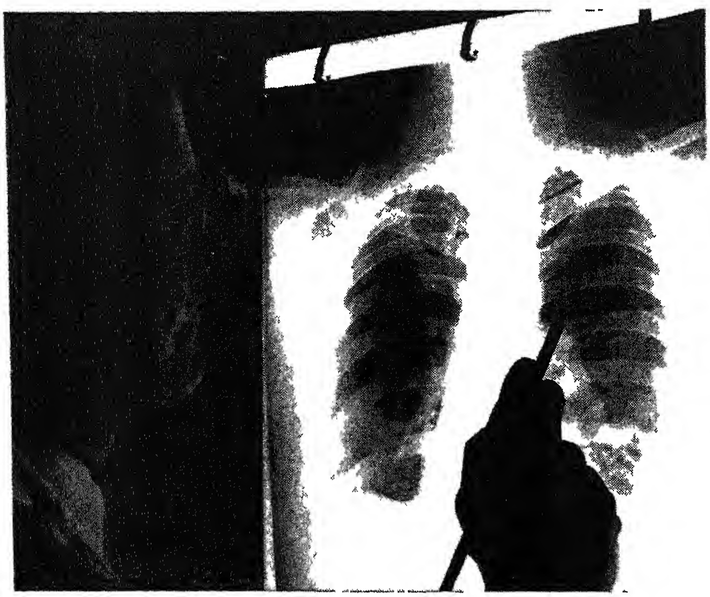
When all the natural defenses of the body fail, infection sets in. The first infection in human beings most frequently occurs in the lungs as the result of inhaling

the bacilli. The capillaries in the area that is attacked become irritated; their walls become more permeable. Plasma and cells then escape from the blood stream into the tissue spaces. Phagocytes are now mobilized to fight the bacilli. All this causes a lesion — that is, an unhealthy change of structure in this particular area. If bacilli escape from the area of infection, new lesions may arise elsewhere in the lung.

Lesions may heal by the process of absorption into the blood stream. In some tissues a small center of infection may harden and may be transformed in time into a hard deposit. Or else tubercles may form: these are clusters made up of phagocytes and living bacilli that have not been destroyed by phagocytes. If all goes well, a network of fibrous tissue will develop around the tubercle; this tissue will seal off any living bacilli from the surrounding normal tissue. The bacilli can do no harm as long as they are imprisoned in this way.

In some cases lesions may develop to such an extent that the tissues of a given area may die. This gives rise to cheese-like debris, which often becomes soft and fluid. Some of it may be absorbed into the system; most of it is expectorated. The area that is left behind after the debris has been removed is called a cavity. If the destruction of tissue becomes widespread, death results. The great majority of persons who are infected for the first time recover completely, and never have any other attacks. The tissues of such persons become highly sensitized to tubercle bacilli invading the body from without or escaping from the tubercles in which they have been walled up. As a result, the defense forces of the body will be mobilized to meet any new invasion more quickly and more effectively than before. In this way some measure of immunity is acquired.

Unfortunately a small proportion of those who have been infected will develop fresh lesions in time. If the body is in a weakened state through exposure or disease, the walls of the tubercles may break down, releasing the bacilli that they formerly enclosed; these bacilli will become centers of infection. Reinfection of this kind is serious; the great majority of fatal cases arise in this way.



A physician pointing out a suspicious spot in an X-ray photograph of the lungs. X-ray examination is the most important method of diagnosing tuberculosis. In an X-ray picture of lungs infected with tuberculosis, significant shadows show up in various shades of gray

Standard Oil Co. (N J)

What are the factors that make some people more susceptible to tuberculosis than others? Heredity plays some part. As for sex, it is true that the tuberculosis death rate is generally higher among males than among females; but there are great varia-

National Tuberculosis Association

Taking an X-ray photograph of the lungs. A routine X-ray examination may show serious infection.

tions in the death rates for the two sexes. Age is a more important factor. The rate of tuberculous infection is high during the first year of life; then it begins to drop. The age period from 5 to 14 in boys and 5 to 12 in girls is the safest as far as tuberculosis is concerned. In the teens, the death rate begins to rise and it reaches its peak in middle age.

Poor diet has at least something to do with tuberculous infection, since it leads to lowered resistance. Physical strain and mental strain are also probable factors. Active infection or reinfection may be spread by such diseases as measles, whooping cough, pneumonia and influenza.

People are likely to have a spread of infection if, in the course of their daily work, they continually inhale dust containing finely divided particles of silica. These particles irritate the lung tissues and thus contribute to the spread of tubercle bacilli. Silica dust may be inhaled by workers in occupations like mining, stonecutting, sandblasting and pottery-making. The introduction of wet drilling, the wearing of respirators and other safety measures have greatly reduced the number of tuberculosis cases among workers in these occupations.

One of the most effective ways to combat tuberculosis is to diagnose the disease as early as possible and then to start effective treatment. Unfortunately, tuberculous lesions may produce no symptoms at all, or else these symptoms may be so slight that the patient may disregard them. He generally does not suspect that he has tuberculosis until there are unmistakable warning signals — loss of weight, chronic cough, the spitting of blood, night sweats, afternoon fever, poor appetite, digestive upsets and a constant feeling of fatigue. By the time all these symptoms make themselves felt, the disease may already have reached a serious stage.

The modern physician has at his disposal a number of instruments and tests for detecting the presence of tuberculosis. For one thing he can analyze chest sounds by percussion — that is, by tapping the chest of the patient with the flexed fingers. Another way of examining the chest is by auscultation — listening to chest sounds with the stethoscope, an instrument developed by the French physician Laënnec.

Limited usefulness of percussion and auscultation

Formerly physicians relied heavily on percussion and auscultation in trying to find out whether the patient had tuberculosis of the lungs. These two procedures still provide *additional* information; but even the most skillful physician can rarely detect the earliest stages of tuberculosis by percussion and auscultation alone.

One of the more reliable methods is the examination of the patient's sputum. If tubercle bacilli are found in it, there can be no doubt that the patient has active tuberculosis of the lungs. Some patients produce no sputum; or else the sputum may show no trace of bacilli, even though tuberculosis is strongly suspected. In such a case, the examination of the stomach contents may reveal the presence of bacilli. An instrument called a bronchoscope may be used to examine the windpipe and its

larger branches or to remove sections of living tissue for laboratory examination.

Another method of diagnosis is the tuberculin test. The substance known as tuberculin was first prepared by Koch in 1890. First he sterilized the fluid medium in which tubercle bacilli were grown in the laboratory; then he filtered it and concentrated it by evaporation to one-tenth its former volume. Koch announced that tuberculin was a cure for tuberculosis; but it soon became clear that this claim was baseless. However, the substance has proved to be extremely valuable in the diagnosis of the disease.

Two tests used in diagnosing tuberculosis

In one method — the intracutaneous test — a small, carefully measured amount of tuberculin is *injected into* the skin. In another method — the patch test — a patch impregnated with tuberculin is *attached to* the skin. If the person who is being tested has been infected with tubercle bacilli, redness and swelling will develop within two to four days around the place where the tuberculin was injected or where the patch was applied. A derivative of tuberculin, called Purified Protein Derivative (PPD), is often used instead of tuberculin in this test and has proved effective.

The most important of all methods of diagnosing tuberculosis is X-ray examination. The density of a substance determines the depth to which X rays will penetrate it. The rays readily make their way through the coarsely woven fabric of the skin, for example, but are blocked to a greater degree by the more closely interwoven tissues of the other parts of the body. Suppose a screen is coated with a chemical that fluoresces, or glows, when X rays strike it. If this screen is placed on one side of the human body and an X-ray tube is operated on the other side, the bones will be shown on the screen as black shadows, surrounded by the fainter shadows of tissues of varying density. This device is known as a fluoroscope. If X rays are permitted to fall on an X-ray film after passing through the body, the bones are shown in white on the film (which is a negative) and the flesh in varying shades of black.

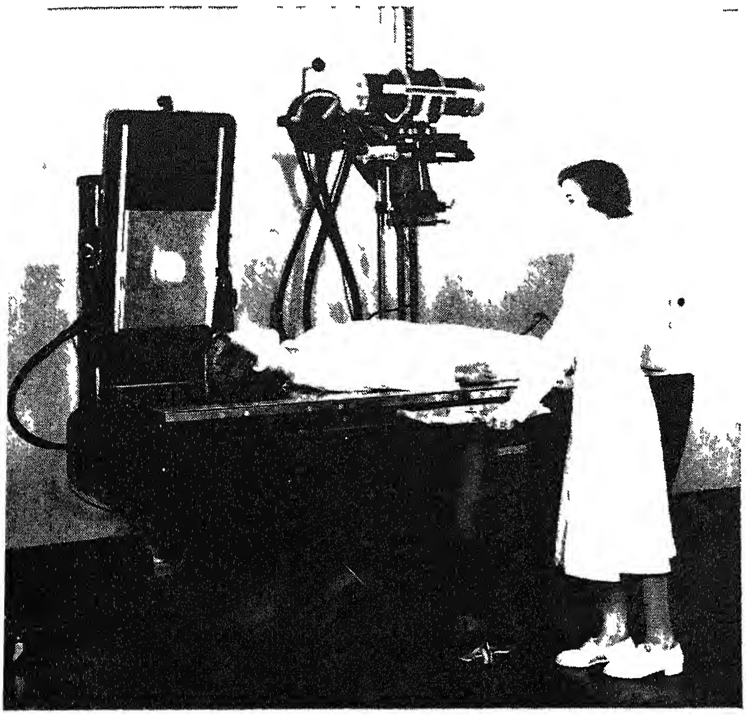
When an X-ray picture of lungs infected with tuberculosis is taken, telltale shadows in varying shades of gray show up on the film. To the physician's trained eye, these shadows may indicate trouble not suspected before, an active advanced lesion or the scars of old arrested tuberculosis.

E. R. Squibb and Sons

A tuberculous Navajo Indian is examined by an attending physician at the Navajo Medical Center Tuberculosis Sanatorium, Fort Defiance, Arizona.

A series of X-ray pictures, taken at intervals, is required to show whether the disease is advancing, remaining stationary or being conquered.

The X ray is not an infallible guide to a diagnosis of tuberculosis, since not all suspicious shadows in the lungs are due to this disease. That is why sputum examination and the tuberculin test are often used to confirm the findings of the X-ray tube. If the fluoroscope or an X-ray picture shows that something is wrong and if sputum examination and tuberculin tests are negative, it is likely that some other disease has caused the trouble. On the other hand, if the tuberculin test is positive and the chest X rays show no evidence of



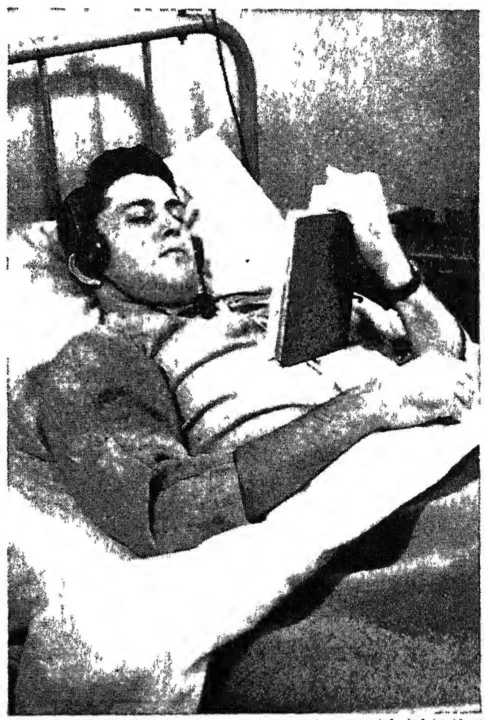
Modern combination radiographic and fluoroscopic unit in operation. With this device the patient's lungs may be examined on the fluoroscopic screen, or else the operator may take an X-ray photograph, which the attending physician can examine at his leisure.

Westinghouse

tuberculosis, this may mean that the affected area is too small to cast a sizeable shadow on the film. It is possible, too, that this area is hidden by some other bodily structure, or that it is in some location other than the lung. The search must then be carried on by other methods.

The basis of all treatment of pulmonary tuberculosis is rest. As we have seen, healing is brought about when a network of fibrous tissue forms around infected areas. At first this network is so delicate that even a moderate pull — such as the pull produced by heavy breathing — may tear it apart. But if the network is permitted to develop, it will have a chance to grow tough and hard, and thus protect the rest of the body from infection. That is why the patient should shun any activities that will cause him to breathe rapidly and heavily; that is why he should rest quietly in bed as much as possible.

In some cases, the patient has to lie flat and he is forbidden to move more than is absolutely necessary. In other cases, he is permitted certain activities, such as drawing or sewing, provided they are car-



Veterans Administration

The basis of all treatment of pulmonary tuberculosis (tuberculosis of the lungs) is rest in bed.

General Electric Company

The United States Public Health Service sends X-ray-equipped buses, like the one shown above, to different communities for mass examinations. Early diagnosis of tuberculosis can often save lives.

ried on while the patient is in bed. It is for the physician to decide how much the activity of the patient is to be limited.

The effectiveness of bed rest depends upon mental relaxation as well as upon bodily relaxation. Some patients can easily adjust themselves to the radical change in their way of life brought about by their illness. Other sufferers may need help in making the necessary adjustments.

Sometimes the *comparative* rest provided by remaining in bed does not suffice. The physician may decide that *complete* rest for the infected lung is necessary. In that case the lung is collapsed so that it cannot be used in breathing; this gives it an excellent chance to heal. One whole lung or parts of both lungs may be collapsed without causing the patient to suffer much inconvenience.

There are various ways of collapsing a lung. In one method, called artificial pneumothorax, a measured amount of air is introduced, by means of a hollow needle, between the lung and the chest wall. The presence of this air crowds the lung away from the chest wall. As air is pushed out of the lung, it collapses. The air that was introduced into the chest is slowly absorbed by the tissues, and the lung begins to fill again in time. To keep the lung collapsed, more air is introduced into the chest: this is called a "refill." The doctor gives a refill whenever necessary — perhaps once a week or twice a month. When it is no longer necessary to keep the lung collapsed, refills are no longer given and the lung returns to normal.

Another method involves crushing the phrenic nerve, which has its origin in the neck and which supplies nerve branches to the diaphragm. (The diaphragm is the partition separating the cavity of the chest from that of the abdomen.) The effect of this operation is to cause the diaphragm on the side of the affected lung to draw up into the chest cavity, thus partially collapsing the lung. This operation can be performed in such a way as to paralyze one side of the diaphragm for a few weeks or months; after that time, the diaphragm again functions normally.

In certain cases the lung is collapsed permanently by surgical removal — partial or complete — of several ribs on the same side of the chest as that occupied by the tuberculous lung. This operation, which is called thoracoplasty, causes the chest wall to cave in on the lung. In many cases a part of the diseased lung, or all of it, is removed by surgery. This is called resection.

Diet is an important factor in the treatment of tuberculosis. The patient should have enough food to supply energy and warmth to his body and to maintain his weight at normal or slightly above normal. He should also have in abundant measure the individual food elements that all tuberculosis patients particularly need. The diet should include (1) milk and cheese for protein and calcium; (2) meat, fish, poultry and legumes for protein, iron and the B vitamins; (3) eggs for protein and iron; (4) green-leaf and yellow vegetables for vitamin A; (5) fruits, especially citrus fruits and tomatoes, for vitamin C; (6) whole-wheat and enriched bread and cereal for iron and the B vitamins; (7) fish-liver oils or concentrates for vitamins A and D.

Veterans Administration

In a tuberculosis sanatorium, skilled physicians and nurses help the patient to fight the disease.

It was formerly believed that tuberculous patients should have a change of climate. Today this is considered desirable only if a physician orders it after a careful study of the case. By and large, the best climate is that in which the patient expects to live after his cure. That is why tuberculosis sanatoria — hospitals for the treatment of patients with tuberculosis — are generally built nowadays near the centers of population. In the United States, for example, not a single state has found it necessary to go outside its own borders to locate its tax-supported sanatoria.

Drugs used in treating tuberculosis

The search for a specific remedy for tuberculosis has gone on hopefully since Koch's discovery of the tubercle bacillus. Early "cures," including tuberculin and gold salts, proved to be complete failures. The sulfa drugs have had little effect on the usual types of tuberculosis in human beings; the same is true of the antibiotic penicillin. Another antibiotic — streptomycin — definitely checks the growth of tubercle bacilli. Streptomycin has brought marked improvement in thousands of cases; it has not proved helpful in some. It is generally used in combination with para-aminosalicylic acid (PAS) or some other drug. The isonicotinic acids also offer considerable promise. It should be remembered that drugs like streptomycin do not kill tubercle bacilli; they serve to hold them in check. To be cured the patient still requires rest, adequate diet and modern hospital care.

If at all possible, the patient should seek treatment in a tuberculosis sanatorium. Here, under the guidance of specially trained physicians and nurses, he learns to live the kind of life necessary for his recovery. His meals are carefully planned to build up his body and increase his resistance. He does not have to worry about spreading tuberculosis to his family, friends and fellow-workers. X-ray equip-

ment and surgical facilities are always at hand. If he needs surgery that cannot be done in his own sanatorium, he may be sent to a larger sanatorium or to a general hospital for this treatment.

In the sanatorium a teacher instructs young people who wish to finish their studies, and helps select correspondence courses for the older patients. An occupational therapist finds interesting things for the patient to do. A librarian provides him with suitable reading matter. A social worker puts his mind at rest by helping to solve the problems that arise through his enforced absence from his home and his work. A rehabilitation worker helps the patient to select and carry through a course of training in a new occupation, if it is decided that his means of livelihood must be changed.

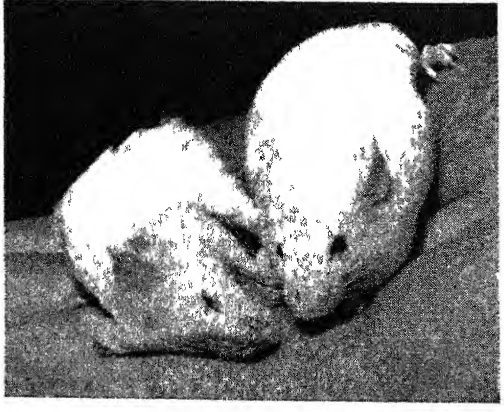
Although by far the best place for a tuberculosis patient is in a sanatorium, patients have been cured at home. In home treatment the physician, the public health nurse, the family and the patient himself must work together as a team. The physician is the captain of this team; he prescribes the treatment to be carried out and the precautions to be taken. The public health nurse helps to interpret the physician's instructions and shows how to carry them out.

The patient should have his own room. Babies and little children should be kept out of this room entirely. No one, except the member of the family responsible for giving nursing care, should go close to the patient or handle the things he has touched. The person giving care should wash her hands thoroughly with soap and water after attending to the patient or handling his belongings. The paper tissues that the patient holds over his mouth or nose when he spits, coughs or sneezes should be burned; if this is not possible, the physician or nurse will give instructions about their disposal. The patient's toilet articles, dishes, eating utensils, linen and bedding must be kept separate from those of the other members of the family. All of these precautions take a great deal of time and trouble.

The fight against tuberculosis is being carried on in many lands by public health officials and by private organizations like the National Tuberculosis Association in the United States and the Tuberculosis Association in Canada. Their chief weapons are education, case finding, rehabilitation and medical research. Through *education,* people are learning the important facts about tuberculosis; they are finding out how to protect themselves from the disease and how to prevent its spread in their communities. Through *case finding,* hitherto unrecognized cases of tuberculosis are being ferreted out; the principal tool used is the chest X ray, but other tests are also applied. Through the promotion of *rehabilitation,* the patient is helped to adjust himself to the life of the community after his medical discharge. Through *medical research* new knowledge of the disease is constantly being acquired.

E. R. Squibb and Sons

This photograph of tuberculous mice was taken nineteen days after they had been infected The healthy-looking mouse on the right had been treated with the drug Nydrazid.



The untreated mouse on the left died a few hours after the picture was taken. Various drugs have proved helpful in treating tuberculosis; they cannot *cure* the dread disease.

INSECT ENEMIES OF FRUIT CROPS

Attacks upon the Apple, Pear, Plum, Cherry, Peach, Grape and Raspberry

MOST APPROVED METHODS OF DEFENSE

NO account of the enemies of plants would be at all satisfactory which did not include a discussion of the various kinds of insect pests that infest our orchards and attack our different varieties of fruits. There are many kinds of these pests that injure fruits and they cause very great losses each year. It is no uncommon thing to find the crop of a certain kind of fruit almost ruined as the result of an attack of some insect, and there is scarcely an orchard or garden in this country that does not suffer more or less injury every year from some one or more of these pests. It has been estimated that the various insect pests in this country which attack the deciduous fruits, such as the apple, pear, plum and the like, cause an annual loss of over $66,000,000. It is impossible to discuss each of the insects that are responsible for this great amount of damage, and we shall have to be content with an account of the life history and habits of a few of the better known and more injurious ones, together with a consideration of the most approved methods of preventing their ravages.

One of the oldest, best known and at the same time most destructive apple pests is the codling moth, which also attacks the pear and quince. An authority on this insect estimates that it causes a loss of over $16,000,000 each year to the fruit growers of this country, to say nothing of its ravages in Europe and other apple-producing countries where it is also found.

The moth is a small gray one, measuring only about $\frac{3}{4}$ of an inch in width when its wings are fully expanded, as shown in Figure 1 on the next page. The moths appear in the spring about the time or very soon after the apples blossom, and in a few days begin to lay their tiny white eggs on the leaves, branches and later on the young apples. In a week to ten days the eggs hatch and the small caterpillars find their way to the young apples, which they enter mostly through the blossom ends. The caterpillar lives within the apple for about one month and burrows through the pulp of the fruit, eating the seeds and causing the apple to fall, or if it remains on the tree, greatly injuring it by the cavities eaten out of the inside (Fig. 2). When the caterpillar has become full grown, it is pinkish white in color and about $\frac{3}{4}$ of an inch in length. About this time the caterpillar makes a burrow to the exterior of the apple and when full grown leaves the fruit and crawls down the trunk of the tree, where it hides beneath a loose piece of bark, spins a cocoon, and either changes to a quiet object called a pupa, or simply rests in its retreat without any change until the following spring. Those caterpillars that spin cocoons and change to pupæ remain in this condition about ten days and then transform to the handsome gray moths that deposit their tiny eggs for a second generation of caterpillars or "worms", as they are usually called. In some parts of this country where the seasons are warm and long there are three or four generations of the codling moth each year. The caterpillars of the last generation pass the winter in their snug retreats and transform to pupæ at the advent of warm weather, and in three or four weeks the pupæ transform to the moths, thus completing the yearly life cycle.

The codling moth has many natural enemies that aid greatly in holding it in check. The eggs and the caterpillars are destroyed by tiny parasites, at least seven having been found to attack the caterpillars. If it were not for parasitic insects, our orchards and gardens would be literally destroyed in spite of all we could do. In addition to the work of the parasites, the caterpillars and pupæ of the codling moth are destroyed in great numbers by different kinds of birds. In fact, there are over a dozen birds that are known to feed on this pest, and they constitute the most effective natural enemies of the codling moth. The nuthatches, chickadees and downy woodpeckers search out the caterpillars in their hiding places beneath loose pieces of bark and devour them. These birds are so efficient in controlling the codling moth that special pains ought to be taken to attract them to our orchards. Pieces of suet tied to the branches will attract the birds and induce them to remain and nest among the trees. But in spite of all these natural enemies, the codling moth is the most destructive insect enemy of apples, and the severity of its injuries and the great losses caused by it emphasize the necessity of taking effective methods of artificial control.

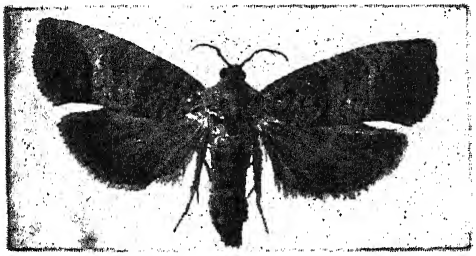


FIG. 1. CODLING MOTH
(enlarged three times)

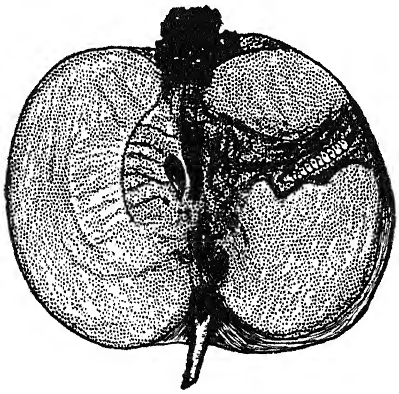


FIG. 2. A "WORMY APPLE"
Caused by the larva of the codling moth.

Fortunately, an effective method has been found for the control of the codling moth. In this country nearly every progressive apple grower sprays his orchard at least twice every season and by so doing protects his crop of apples from becoming wormy and unfit for market. As soon as three-fourths or all of the blossoms have fallen the trees are sprayed with paste arsenate of lead at the rate of 5 pounds to 100 gallons of water. The young apples are just forming, and at this time they stand upright (Fig. 3) with the small brown leaves called the calyx at the blossom end spread wide open. Great care is taken at this time to put the spray mixture into the blossom end of the apple down in what is called the calyx cup, for it is here that the tiny caterpillar enters the apple and takes its first meal. In a few days the calyx cup closes tightly and it is too late to spray, but if the poison mixture has been sprayed into the open cup, it will remain there a long time awaiting, as it were, the coming of the tiny "worm". This is the most important spraying for the codling moth and should be done thoroughly and with great care. Since some of the caterpillars enter through the sides of the apples and therefore do not eat the poison placed in the blossom end, a second application of the poison is recommended about three weeks after the first one. Finally, many apple growers often make a third application in mid-summer to poison the caterpillars of the second brood.

Formerly, burlap bands were put around the trunks of apple trees to form places beneath which the caterpillars would crawl to spin their cocoons. By examining the bands now and then and crushing the caterpillars found beneath them many were destroyed. It is now known, however, that spraying is much more effective in killing the caterpillars, and burlap bands are seldom used.

The woolly aphis is a serious pest of the apple, especially in the warmer parts of this country and in England and Europe. Unlike the codling moth, however, it attacks the tree itself and on an infested tree the insects are usually present on the roots below ground as well as on the branches. The tiny aphids have the habit of secreting fine, white, waxy threads through pores in their bodies and when many of them are congregated in a group along a branch the twig appears to be covered with a white cottony growth (Fig. 4, number 3). If the cottony material is closely examined, the bluish bodies of the aphids will be found beneath it, each aphis with its tiny slender beak inserted into the bark for the purpose of sucking up the sap of the tree. They delight in clustering about a wound made in cutting off a branch or in breaks in the bark. As a result of their presence in these situations, scars, enlargements and deformities of the branches are caused, and if the aphids are abundant enough, the foliage of the tree becomes sickly and pale yellow, while young trees that are badly infested at the roots are easily blown over by the wind because so many of the roots have become decayed and broken off.

FIG. 3. YOUNG APPLES
At the proper stage for spraying for the codling moth.

The life history of the woolly aphis of the apple is not yet wholly understood. First it is to be noted that some of the aphids live above ground on the branches while others live below the surface on the roots of the tree. Those living below ground cause knots or galls on the roots and finally bring about their decay.

During the summer the wingless, cottony-covered aphids may be found on the branches and on the roots of infested trees. Generation after generation is produced during the warm season in these situations, but in autumn a wonderful thing happens. Suddenly a generation of aphids appears the individuals of which have wings and some of these fly or are blown to near-by elm trees. Here the true males and females are produced and each tiny, wingless female lays a single dark oval egg in the crevice of the bark on the elm tree. It is said that females are produced also on the apple tree and that eggs are also laid there. But it would seem that most of the eggs are laid on the elm as we have described. The eggs remain on the bark over the winter and hatch, in the spring, into wingless aphids which may be found on the buds of the elm. Here other aphids are born and in feeding on the leaves cause them to swell and curl. Bunches of infested elm leaves covered with white woolly aphids may easily be found in the spring on many elms. Later, a generation of winged aphids is produced and some fly back to the apple, where they reinfest the tree.

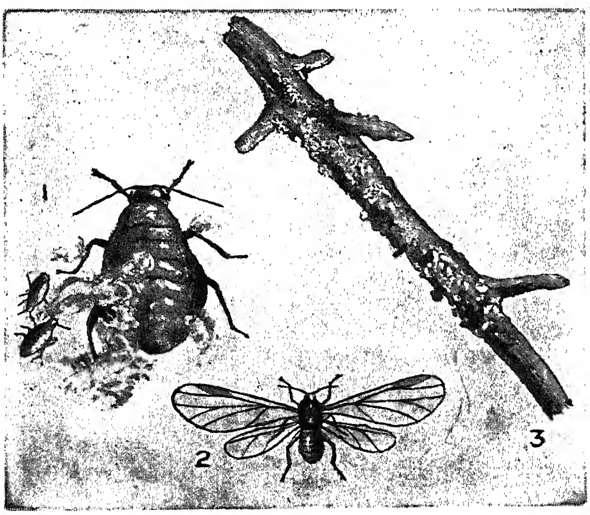


FIG. 4. THE WOOLLY APHIS, OR APPLE-ROOT LOUSE
1, wingless viviparous female; 2, winged female; 3, apple twig covered by woolly aphids.

Fortunately, the woolly aphis is held in check by several enemies, among which are certain tiny parasites. The aphids are also devoured by the larvæ and adults of several species of ladybird beetles and by the larvæ of lace-wing flies and of certain true flies known as the "syrphus flies". Undoubtedly birds feed upon them and aid in holding them in check.

The aphids on the branches may be killed by spraying the tree thoroughly with a 15 per cent kerosene emulsion. This may be made by dissolving half a pound of soap in one gallon of water and adding two gallons of kerosene. While the

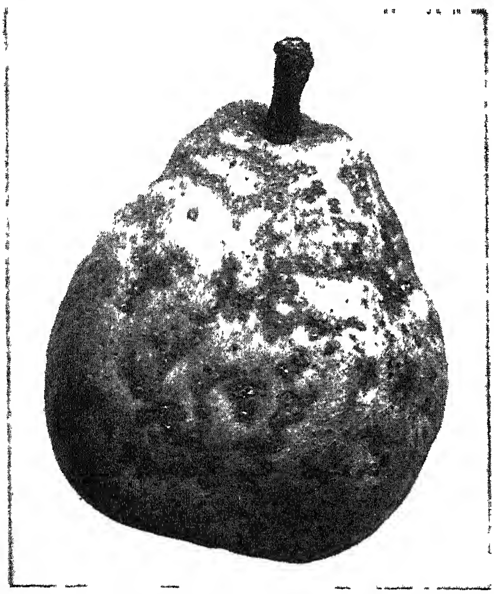


FIG 5. A PEAR BADLY INFESTED WITH THE SAN JOSÉ SCALE

water is quite hot the mixture should be thoroughly agitated until a white, creamy emulsion is formed. This stock solution should then be diluted with $10\frac{1}{3}$ gallons of water to form a 15 per cent emulsion.

The aphids underground are much harder to destroy. In the first place one should not accept trees from the nursery which are infested with the woolly aphis. Considerable experimental success has been had in this country by soaking the soil around infested trees with a 15 per cent kerosene emulsion. The soil is first removed around the tree over a circular area of $1\frac{1}{2}$ to 4 feet in diameter, depending on the size of the tree, and to a depth of 3 inches. The soil is then soaked with the emulsion, 3 gallons on the smaller area and 6 gallons on the larger, after which the earth is replaced.

The San José scale, which would better be called the Chinese scale because it originally came from China, is another very serious pest of the apple in America, and it has also become established in Japan, Australia, Chili and Hawaii. European countries have so far been able to keep it out of their territories by rigid quarantine. It not only attacks the apple but is a very serious pest to the pear, peach, plum, prune, apricot and currant (Fig. 5). In fact, it thrives upon a great variety of fruit trees, shrubs, shade and forest trees.

It was first discovered in this country near San José, Cal , where it was probably introduced about 1870 on imported plants. It was first known to science and first given a name in 1880. Since that time, however, it has spread into nearly every state in the United States and has reached many sections in Canada. The San José scale attacks all parts of the tree above ground, and when abundant kills the infested plants. On badly infested trees, especially peach trees, the branches become completely covered by the tiny insects and appear as though enveloped in a grayish incrustation. Each female insect has a long, slender beak which she forces through the outer bark into the tender, sappy layers beneath and sucks up the nourishment from the tree.

Each tiny insect is covered with a small waxy scale, which in the case of the female is circular and about the size of a pinhead (Fig. 6). The body of the female is yellowish, and she has no legs or wings and consequently cannot move about after once becoming established beneath her waxy house. The male, after a short time, develops an elongated scale and becomes furnished with wings with which it can fly. Curiously enough, the male insect has no mouth parts fitted for taking food and does not live long after it becomes full-grown.

The insects pass the winter in a partly grown condition on the infested trees beneath their tiny, almost black, waxy scales (Fig. 7). In the spring the mother insects produce many young ones that crawl out from beneath the mother's scale and go in search of places where they can push their beaks into the bark and settle down for life. Each one looks like a minute, yellowish white mite at first, but after it settles down on the bark, it soon begins to form the waxy covering over its body and in a short time becomes entirely hidden beneath the scale. In about 45 days the young scale insects become full-grown and ready to produce another generation. During a single season there may be two or three generations, depending on the length of the summer; and since each mother scale is capable of producing from 100 to 500 young, a tree infested with a comparatively few scales in the spring may become fairly incrusted with them by the end of the season.

Although the San José scale insects are no longer than the head of an ordinary pin, yet there are at least nine species of wasp-like insects that are small enough to deposit their eggs in or on the bodies of them. Each tiny parasite finds food enough in the body of a scale insect to grow and become mature, and there can be no doubt but that these nine different parasites do very much good in destroying the San José scale. In addition, there are about a dozen ladybird beetles that prey upon this pest.

Finally certain fungous diseases attack the scale insects and cause their death. Despite this large array of natural enemies the San José scale has been one of the worst insect foes the fruit grower has ever had in America, and much time and money have been spent and are being spent in fighting it. The most effective way is by spraying the infested trees, either with some form of oil emulsion or, more generally, with what is known as the lime-sulphur wash, made by boiling a certain amount of lime and of sulphur in a given quantity of water for a definite length of time. When the boiling is completed a concentrated solution will result, which must be diluted before using by the addition of water. Even then it is so caustic that it can be applied only during the dormant season, either late in the autumn after the leaves have fallen or early in the spring before the buds have started. Splendid success has been obtained with the wash in America. In fact, the lime-sulphur wash has saved many an orchard in the United States from total destruction. It is applied with a strong force pump, in most cases nowadays with large power sprayers capable of maintaining a pressure of 150 pounds or more per square inch.

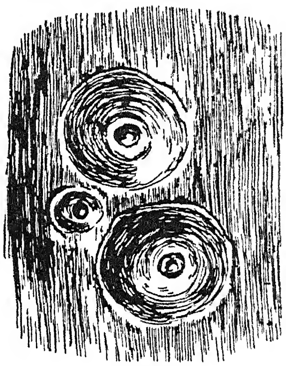


FIG 6. FEMALE SAN JOSÉ SCALE INSECTS (much enlarged)

FIG. 7. A BRANCH INFESTED WITH THE SAN JOSÉ SCALE

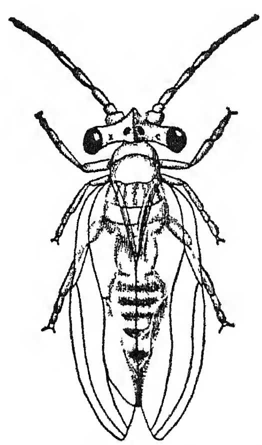


FIG. 8. AN ADULT PEAR PSYLLA (much enlarged)

The pear psylla is perhaps the chief pear insect pest in this country, especially in the East. It was introduced into the country from Europe probably about

1832 and has thriven here even more vigorously than in its native home. The fully grown psylla is only about $\frac{1}{10}$ of an inch in length. It is dark reddish brown in color and has four delicate thin wings, large eyes and two slender antennæ (Fig. 8). It has sucking mouth parts like the San José scale, and when multitudes of young psyllas are present they cause such a drain that the infested tree becomes sickly in appearance, the leaves turn brown and drop off in midsummer. The effect is such that the tree fails to make growth or to produce fruit buds for the

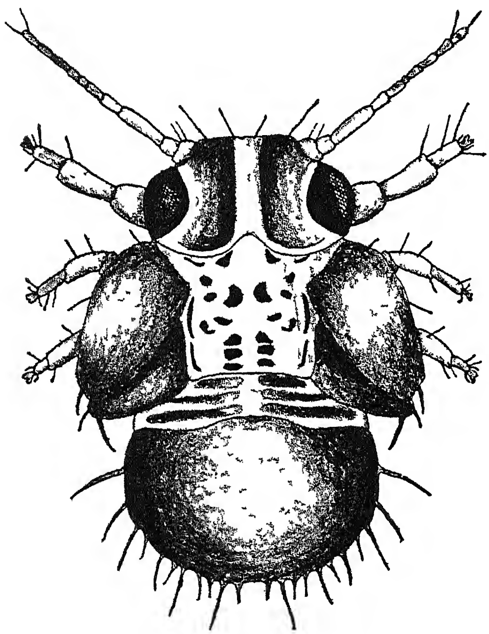


FIG. 9. A YOUNG PSYLLA (much enlarged)

next year, thus cutting short the succeeding crop. If nothing is done to check the pest, the trees will become weakened and unable to withstand the attacks of future hordes of the psyllas, the blight, rust and other enemies that always come to exhausted plants. Moreover, each psylla secretes minute drops of a clear sweet liquid known as honey-dew, which finally spreads over the leaves, branches and fruit in a sweet sticky coating. The honey-dew offers a favorite medium for the growth of a black, sooty fungus that soon coats the leaves, branches and fruit wherever the sweet material has lodged. This fungus does no particular harm to the tree except to give it a forbidding appearance while the fruit is so blackened that it has sometimes to be washed before being presentable for the market.

The full-grown psyllas pass the winter in crevices of the bark or in the crotches of branches beneath accumulated leaves, and with the first warm days of spring become active and begin to lay their tiny orange-yellow eggs about the buds and along crevices in the bark of the smaller branches. The eggs hatch in two or three weeks, depending upon the temperature, and the young psyllas begin at once to suck juices from the tender leaves. The young psyllas are wingless but active and grow rapidly so that they become full-grown in two or three weeks (Fig. 9). Thus the whole life cycle, in the height of the season, may be passed through in one month. There is time for four broods, at least, so that toward the end of the season the psyllas are often present in enormous numbers and cause very great injury.

This pest of pears has proved to be a very difficult one to control. One must not expect to check it successfully without thorough and persistent effort. Perhaps the most effective material for the destruction of the young and adult psyllas is a commercial product of tobacco known as "nicotine sulphate". The advantage of this commercial product is that it contains a known amount of nicotine, 40 per cent in the better known brands, and can be used intelligently. Tobacco extracts can be made by steeping stems in water, but since tobacco varies greatly in the amount of nicotine it contains one never knows what strength of solution is obtained.

The adult, over-wintering psyllas may be killed by spraying the trees thoroughly in the late fall or early spring while the tree is dormant with nicotine sulphate (40 per cent) at the rate of $\frac{3}{4}$ of a pint to 100 gallons of water. To this amount of mixture there should be added 4 or 5 pounds of soap which will cause the tobacco solution to stick and to spread better than it otherwise would.

The adults are very active, and it is probable that not all of them will be hit by the liquid, in which case those that escape will remain to deposit eggs later. As soon as the eggs hatch and the young psyllas appear they may be very effectually destroyed by spraying the trees with the same solution. In heavily infested orchards two or three successive applications, a few days apart, may be necessary. The addition of 25 pounds of hydrated or quicklime to each 100 gallons of the mixture has proved of value.

Plums are often scarred on the outside and often contain "worms" inside next to the pit. In the majority of cases the scars are due to the work of the plum curculio and the white, half-curled "worm" inside is the larva or grub of this insect. The plum curculio is undoubtedly the most important insect pest of the plum, although it by no means confines itself to this fruit. It attacks the apple, peach, cherry, apricot and pear in about the order of importance named. The plum curculio is a native insect and is widely distributed throughout the middle and eastern United States. One authority estimates that it causes a yearly loss of over $8,500,000, and although it has been known as a fruit pest for over a century no wholly satisfactory method of control has yet been found.

The full-grown curculio is a small, mottled, black and grayish beetle about $\frac{1}{5}$ of an inch in length, with two prominent humps near the middle of the back and a long, slender, trunk-like snout or proboscis with a pair of sharp and efficient jaws at the end. The small beetles pass the winter hidden beneath leaves and rubbish along old hedgerows, and in the borders of woodlands. In the spring they appear and begin to attack plums, apples, peaches and other fruits. The curculio makes two kinds of scars on the outside of the plums. One known as the feeding scar is a circular, shallow pit caused by the beetles feeding on the fruit. The other made by the female in depositing her egg is very characteristic because it is crescent-shaped and usually very clearly so (Fig. 10). The female curculio makes a hole in the pulp of the fruit with her snout, then deposits a white egg in it and then with her snout cuts a crescent-shaped scar just in front of the hole (Fig. 10) The egg hatches in a few days and the whitish grub burrows through the flesh In about 20 days it becomes full-grown and then enters the soil under the tree to the depth of an inch or two, where it makes a tiny chamber and changes to a pupa In about four weeks from the time the grub goes into the ground the full-grown beetles come forth and feed for a time on the fruit remaining on the tree and then hide away in their winter retreats, thus completing the life cycle, there being but one generation each year

Cleanly cultivated, carefully pruned and well-cared for orchards are less subject to the attacks of the curculio, and this is true of many insect pests Old hedgerows, stone walls and fences grown up to vines, bushes and weeds surrounding the orchards should be cleared away, because it is in such places that the curculios find favorable places for passing the winter. Frequent and thorough cultivation of orchards during July will break up the cells of the pupæ and bring about their destruction. The trees should be judiciously pruned, for direct sunlight on the infested fruit lying on the ground will kill the grubs. Finally, the trees should be sprayed soon after the petals fall and again ten days later with arsenate of lead, 5 pounds in 100 gallons of water, or of Bordeaux mixture, the latter often being used to control the brown rot, a common disease of plums.

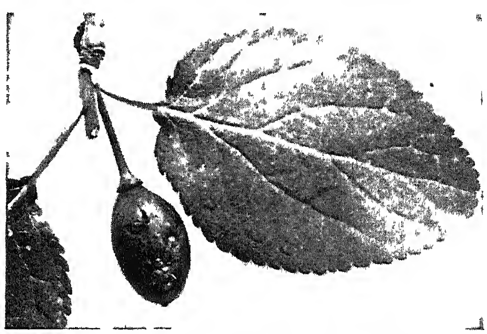


FIG. 10. A PLUM SCARRED BY A CURCULIO

In some localities in our country it is next to impossible to grow cherries that are free from "worms". Some of these "wormy" cherries are caused by the grubs of the plum curculio, but many of them, especially in the northern United States, are due to the cherry maggots, which are the small, white larvæ of certain flies that deposit their eggs just beneath the skin of the fruit. There are two species of these cherry fruit-flies, but they are so nearly alike in size and appearance that only an expert can tell them apart Each one is a little smaller than an average house-fly, and each of them has dark stripes or bars running crosswise of the wings. They appear about the time the cherries begin to redden and soon begin to thrust their tiny white eggs into the cherries. Here the eggs hatch and the small white maggots begin to burrow through the flesh of the cherry, especially around the pit (Fig. 11). In three or four weeks the infested cherry becomes sunken on one side and decay sets in, although the fruit does not fall from the tree. Even at picking time many of the "wormy" cherries show no indication from the outside of the presence of the maggot within.

FIG. 11. A CHERRY INFESTED WITH THE MAGGOT OF A CHERRY FRUIT-FLY

When the maggots become full-grown they leave the cherries and go into the ground to the depth of about one inch and change to hard brown puparia, which remain in the soil until the following spring or nearly ten months. There is, therefore, but one generation a year.

These flies attack both sweet and sour cherries, the Morellos and Montmorencies usually suffering the worst.

Careful observations have shown that the flies are in the habit of sucking up drops of moisture that they find on the leaves of the tree. Advantage has been taken of this habit by spraying the trees with a small amount of sweetened, poisoned water. Most satisfactory results have been obtained by using arsenate of lead at the rate of 5 pounds to 100 gallons of water and adding 3 gallons of cheap molasses to sweeten it. Each tree should be rather thoroughly sprayed with this mixture, although a heavy coating is not necessary. The sweetened bait is easily washed off by rain and should be renewed after a storm.

The peach is subject to the attacks of a number of rather serious insect enemies, but perhaps the peach-tree borer is the most common and most important of all. It is found in the United States and Canada east of the Rocky Mountains wherever the peach is grown, while along the Pacific Coast a closely related species with very similar habits exists and constitutes a troublesome pest. It is estimated that the peach-tree borer causes an annual loss in this country of at least $6,000,000. Trees of all ages are attacked and young trees are often killed outright, while older trees are greatly weakened in vitality and resistance to the attacks of other pests.

The borer is the caterpillar of a beautiful steel-blue moth (Fig. 12). When full-grown it is yellowish white in color and about one inch long. It spends its life just under the bark of the larger roots and also of the trunk, usually below the surface of the soil, where it makes furrows partly in the bark and partly in the sapwood, sometimes completely girdling a tree (Fig. 13). The presence of the borers causes the exudation of large masses of gum which may be found on the ground around the bases of infested trees. These accumulations of gum are a pretty sure indication of infestation by this insect.

The borers pass the winter in their burrows, complete their growth in the spring and change to pupæ in rough brown cocoons made partly of silk and partly of particles of bark and other débris.

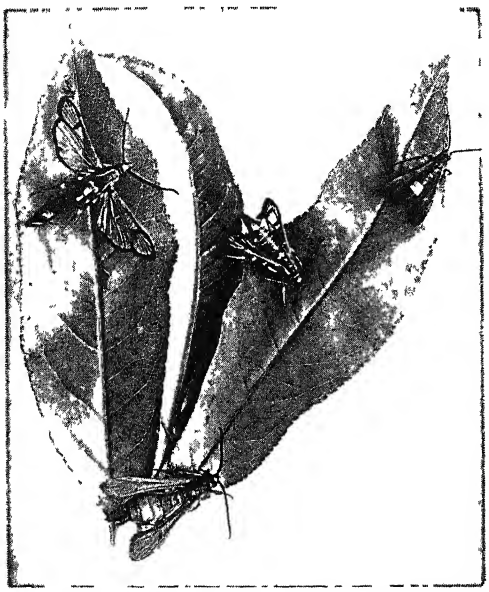


FIG. 12. ADULT MOTHS OF THE PEACH-TREE BORER

The cocoons may be found at or near the surface of the ground at the base of the tree in July and August. In three or four weeks the pupæ change to the parent moths.

The male and female moths are considerably different in their appearance. Both have steel-blue bodies, but the abdomen of the female differs from that of the male in having a broad orange-yellow band around the middle. In addition all four wings of the male are transparent, while only the hind wings of the female are clear, the front pair being thickly covered with blue scales (Fig. 12). The female moth deposits many tiny eggs on the trunks of peach trees in July and August. Here they hatch into the tiny borers which enter the bark and cause the injury as explained. Thus there is but one generation each year.

Many washes and many devices have been tried to prevent the attacks of this insect, but without much success until recently. In fact, the most common way of controlling it has been to dig the borers out at least once a year. In digging out the borers the earth is hoed away from around the base of the tree to a depth of three or four inches. The masses of gum will indicate where the larvæ are at work and with a sharp knife the bark can be cut away and the borers exposed in their burrows and killed. In badly infested orchards the borers may be dug out in the fall and in the spring during the first part of June.

Recently a white crystalline substance known by the long chemical name of para-di-chloro-benzene has been used with fine success. In applying the material the crust of earth is scraped away around the base of the tree. Then $\frac{3}{4}$ of an ounce to 1 ounce of the crystals is scattered in a band about two inches wide all the way around the trunk (Fig. 14) and promptly covered with two or three shovelfuls of soil packed down with a few strokes from the back of the shovel. The para-di-chloro-benzene should be applied in the northern states about September first, while in Georgia about October first would be the proper time. It should not be used, however, on trees that are less than six years old.

FIG. 13. TRUNK OF A PEACH TREE INFESTED WITH THE PEACH-TREE BORER

During the last two decades the grape industry in the eastern part of this country has suffered greatly from a comparatively new pest, the grape root-worm. The rose-chafer and the grape-vine flea-beetle have also, during this period as well as previous to it, contributed to the losses to which grape growers have been subject from year to year. But perhaps the most common and widespread insect enemy of the grape is the grape leafhopper. It is present and more or less injurious in nearly every vineyard in the United States and Canada and, in some seasons, is very destructive. In California it is, next to the phylloxera, the worst insect pest of the vine.

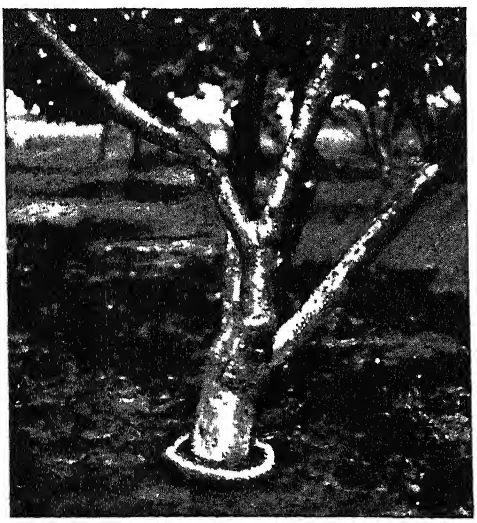


FIG. 14. PEACH TREE TREATED WITH A RING ($\frac{3}{4}$ ounce) OF PARA-DI-CHLORO-BENZENE

Both the young and the full-grown hoppers live on the leaves of the grape and with their tiny beaks suck up the sap and deprive the vine of its requisite nourishment. As a result of this, the leaves turn brown and fall from the vine, the fruit does not mature and ripen properly, and the vine itself is prevented from developing new wood for the production of grapes during the succeeding season.

The leafhoppers when full-grown are light in color but mottled with darker spots, and are scarcely an eighth of an inch in length. When abundant they fly up in swarms if the vines are disturbed. They pass the winter hidden away in the grass and leaves along ditch banks or the borders of woodlands. In the spring they come forth from their hiding places and begin feeding upon almost any green plants they can find. Later, as soon as the foliage appears, they go to the grapes, where they live almost entirely on the under sides of the leaves. In two or three weeks they begin to thrust their tiny eggs into the tissues of the leaves just beneath the lower skin. The eggs hatch in ten days to two weeks, but it takes about one month for the young hoppers to become full-grown.

In California and such localities where the season is long there are two full broods each year and the hoppers become exceedingly abundant in July and August. The foliage turns brown and the leaves fall, while the fruit fails to ripen and does not acquire its proper color, flavor or sweetness.

In the case of the leafhopper we have a pest for which clean culture is decidedly beneficial. Hedgerows, grassy ditch banks and borders of near-by woodlands should be cleaned up to destroy the winter hiding places of the insects. In addition, clean cultivation of vineyards to destroy the weeds and plants upon which the hoppers live in the spring before the foliage of the grape appears, is of very material aid in holding this grape pest in check.

In California some vineyardists make a practice of catching the hoppers in mosquito-screen cages. The cage is smeared on the inside with kerosene or crude oil and is set over an infested vine. By jarring the vine the hoppers are disturbed and are caught in large numbers when they strike the oil.

In eastern vineyards the hoppers are controlled by spraying the vines with nicotine sulphate (40 per cent) at the rate of 1 part to 1000 parts of water. Thorough work is necessary, for the young hoppers must be hit with the liquid in order to be killed, and the spray must therefore be directed upwards and on to the under sides of the leaves, if one is to expect any real success with its use.

Raspberries are fairly free from insect enemies; in June, however, one will sometimes find the tender tips of the new shoots wilted and fallen over. One can be almost sure that this type of injury is the work of the raspberry cane-borer. The adult insect is a slender, handsome beetle about half an inch in length. The body is black except for the area just behind the head; this is reddish yellow and bears two or three black spots on the upper side.

The cane-borers appear in June. The female deposits her eggs in the pith of the tender shoots of the raspberry. Before doing so, she girdles the cane in two places about half an inch apart, and then she inserts the eggs into the cane between the two cuts. As a result of the girdling, the tip of the cane wilts and drops over to one side. After an egg hatches, the grub bores down the cane toward the root. It does not get far the first summer. The next season, however, it reaches the base of the cane and kills it. The following spring the grub goes through its transformations and the parent beetle appears, thus completing the life cycle.

This pest is best controlled by cutting off the wilted shoots two or three inches below the girdles. The custom of cutting out and burning the old dead canes every fall is a good one, because in this way many of the larvae are destroyed before they have become adult beetles.

An insect that has caused a great deal of damage to vegetable crops as well as to garden plants and trees in many areas of the United States is the Japanese beetle. This insect is a native of Japan; it was introduced into the United States some time before 1916, when it was first found near Riverton, New Jersey. When fully grown, the Japanese beetle is about a half inch long and a quarter of an inch wide. Its metallic green body is oval-shaped; the hard outer wings are coppery brown. The insect lays its eggs in medium-moist loamy soil. The larva hatches toward the end of the summer; it does not emerge from the soil, however, until June, or later, of the following year. The normal life of the beetle is from thirty to forty-five days. Feeding is confined chiefly to the foliage on the upper and outer parts of garden plants and trees exposed to bright sunlight; the insects also attack early-ripening fruits, especially apples, peaches and plums. Among the plants attacked by the Japanese beetle are apple, peach and cherry trees, sweet corn, roses, Virginia creepers, dahlias, hollyhocks, elms and willows.

Various measures have been taken to fight the Japanese beetle. Parasitic insects that feed on the larvae of the beetle have been introduced into infected areas. Many beetles are caught in traps, baited with a mixture of geraniol and eugenol. Contact sprays have also proved effective.

The most valuable of the newer insecti-

U. S. Dept. of Agriculture

PEACH TREE INFESTED BY JAPANESE BEETLES

cides is DDT (dichloro-diphenyl-tricholoro-ethane), a chemical of great toxic powers. In mixtures of 5 to 10 per cent, it is deadly to most insects. When applied to walls or screens as a wash, DDT is effective for months. It is sometimes used as an ingredient of paints. It helps control lice, bedbugs, flies and mosquitoes; in the field it aids the farmer in his fight against a host of crop pests. Since DDT is harmful to many useful insects as well as to certain birds, it should be used cautiously. Sometimes insects develop resistance to DDT; when this occurs, nonchlorinated insecticides are substituted for it.

PRAIRIE CHICKEN

Photos American Museum of Natural History, N. Y.

WILD TURKEY

OUR COMMON BIRDS VII

The Wary Grouse, Vanishing Turkeys,
Friendly Quail and Gorgeous Pheasants

THE UPLAND GAME BIRDS

THERE are many ways in which birds serve man, but none has been recognized for so long a time as those of food and sport. Ever since man began throwing stones, the flesh of birds has formed an important item in his diet. With the coming of agriculture and the domestication of animals, birds assumed an even more important part in the economy of the table, and today millions of dollars are spent each year in raising domesticated birds so that man can vary his diet of beef and pork and mutton. The strangest part of it is that so few birds have entered into the economy of man. All our domestic ducks, with the exception of the muscovy, have come from the mallard; all our pigeons from the rock dove; all our turkeys from the Mexican turkey; and all our various breeds of chickens from the red jungle fowl of India. Other closely related species have given us nothing. It is one of the ways of nature to select one species for glorification.

Mother Nature is a great specializer. Every organism develops and becomes specialized or adapted for some particular function. Some are constructionists and others are destructionists, and always the two are balanced. The plants are the builders and the animals are the destroyers. And lest some of the destroyers become too numerous, other animals are the destroyers of these.

In the course of ages, this is the only way in which life can continue to exist. Otherwise there could be no progress, and each organism by its own growth and multiplication would starve itself and all others into non-existence.

In this scheme of nature, there is one group of birds which seems to be designed to be the legitimate prey of the larger carnivorous birds and animals, including man. This is the group of game birds. Their habits are such as to develop the greatest bulk of meat for their size, and their food is such as to give to it a tenderness and flavor highly desired. Their food habits are not such as to make them needed in fighting the insects, their colors are usually dull, and they have no songs. Indeed, their greatest charm is in their wildness and the subconscious knowledge that they are prized as food. Some of these game birds frequent the lakes and marshes, others the upland woods and fields. The latter include all of the fowl-like or gallinaceous birds which are treated in this chapter.

Some authorities place all of these gallinaceous birds, the turkeys, grouse, partridges, quail, guinea fowls, pheasants and peafowls, in one family, *Phasianidæ*, but here in America we are accustomed to put each group in a family by itself. Thus we have the *Tetraonidæ* or grouse, the *Odentophoridæ* or partridges and bob-whites, the *Meleagridæ* or turkeys, etc. There is likewise considerable confusion in the usage of the common names "grouse", "partridge" and "quail". These names are applied to quite different birds in different parts of the country and interchangeably in others. It would be difficult to convince most hunters in the northern United States that the ruffed grouse was not a partridge, and that the bob-white is not a quail, but strictly speaking, the true quails are all Old World members of the

family *Perdicidæ*, and the New World bob-whites, California quail, etc., belonging to the family *Odontophoridæ*, should be called partridges or perhaps New World quail. This takes the name "partridge" away from all the grouse which belong to the family *Tetraonidæ*. Finally, the name "pheasant" is just as inappropriate for the members of the grouse family as "turkey" would be for the pheasants, and yet in some parts of the country the ruffed grouse is called the pheasant. In general, grouse can be distinguished by having the tarsus or lower leg more or less covered with feathers, in some species extending to the tips of the toes. The partridges or New World quail have the tarsus bare and without spurs, while the pheasants have it bare but with well-developed spurs.

The wary grouse

There are about 25 species in the grouse family, confined to the northern parts of the northern hemisphere, two species of ptarmigan being circum-polar and found both in Europe and America. The majority of species, however, are more or less restricted in their range, and the individuals are often sedentary and spend their entire lives within the confines of a small woodland. During the nesting season they are solitary, but afterwards the young stay with the parents, and sometimes different families come together about good feeding spots, and good-sized covies are formed.

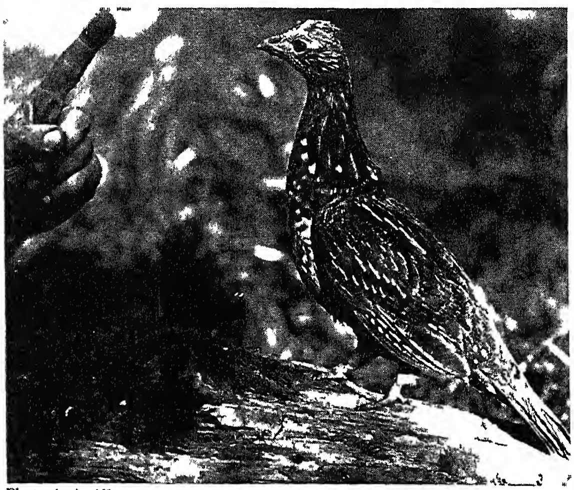


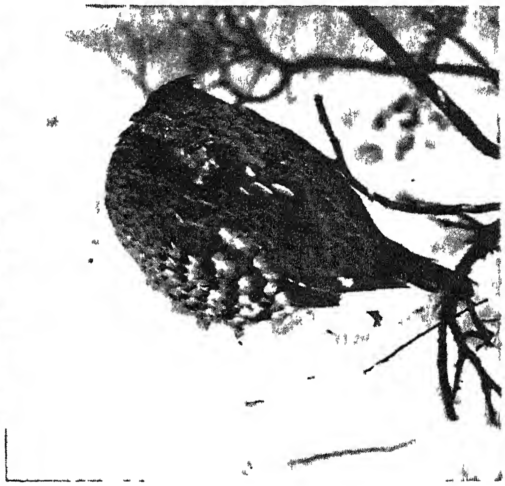
Photo A A Allen

A HAND-REARED RUFFED GROUSE THAT LIKED TO PLAY

Grouse are ordinarily terrestrial, although when alarmed they often fly up into the trees, and during the winter they secure a good deal of their food from the buds. They are not shy unless hunted continuously but allow a close approach, relying upon their protective coloration. When they do fly, it is with a startling whir of the wings that is quite disconcerting to the average hunter. Their flight is rapid and direct, although they usually follow the arc of a circle and do not fly far. Indeed, when flushed several times, and driven to the edge of its circumscribed area, a grouse will often double back right over the head of the pursuer.

Grouse ordinarily nest on the ground, the woodland species at the foot of a tree or beneath a fallen branch, and lay from eight to fifteen eggs. The young are covered with down when hatched and are able to run about. Their wing feathers are the first to grow, and they are able to fly when about a week old although they are still very small. The male bird does not ordinarily help in their care. Indeed, he is usually never seen near the nest or brood until they are full-grown. The female, however, is very solicitous for the safety of the young and uses every expedient to distract the pursuer, trailing her wings along the ground as though severely wounded, to attract attention to herself rather than to the young, and hissing like a snake or even flying into the face of the pursuer. The young crouch at the danger call and do not move until once more called by the mother. As they are always scattered it makes it a very difficult task to find them, so protectively colored are they.

The best known of the grouse family are the ruffed grouse, the spruce grouse and the heath hen of the East, and the dusky or blue grouse, the Franklyn's grouse, the prairie chicken, the sharp-tailed grouse and the sage grouse of the West. The northern ptarmigan are represented in



Photos by A A Allen

RUFFED GROUSE STRUTTING
(Bird raised in captivity.)

RUFFED GROUSE IN WINTER
Puffed out to keep warm (captive bird)

Colorado by what are locally known as "white quail", a southern form of the white-tailed ptarmigan.

The most generally known, and the game bird par excellence, is the ruffed grouse which in one or another of its forms is found in wooded districts from Virginia to Alaska. It gets its name from the tufts of large black or brown feathers on the sides of the neck which can be lifted and spread until the head is framed as in an Elizabethan ruff. The broad, banded tail is always spread when the bird flies and is one of the simplest ways of distinguishing it from a female pheasant or any other of the game birds. Before they learn the fear of man and the gun, ruffed grouse or "partridges", as they are generally called, are tame birds and merely walk out of one's way along the forest trails, but it takes but very little hunting before they become shy and it taxes the utmost skill of the hunter to approach them even with the aid of a dog trained to "point".

The most interesting characteristic of the ruffed grouse is its habit of drumming. The cock bird selects some fallen log to which he returns often for years. Drumming is at its height during the spring but even after the breeding season, on bright days during the fall and winter, the old cock may come back to his favorite log

Photos by A A Allen

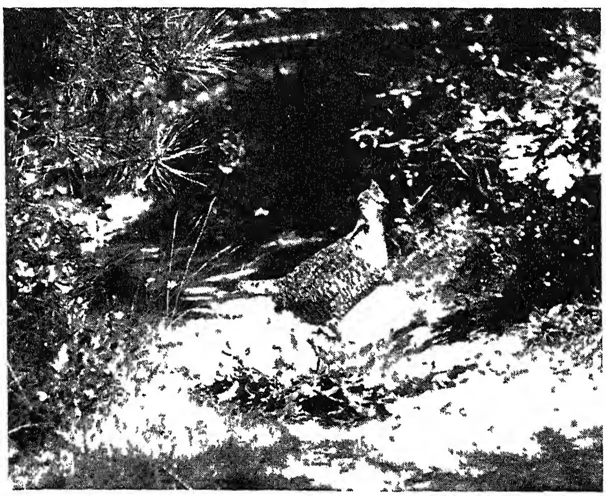
NEST AND EGGS OF RUFFED GROUSE

YOUNG RUFFED GROUSE HATCHING

The nest is at the foot of a stump.

The drumming sound, which begins with a measured thump — thump — thump and ends with a loud whirring sound like the muffled sound of a motorcycle engine, is made by the cock beating the air with his wings. Between his drumming performances and while waiting for the female to approach, he struts up and down the log much like a miniature turkey gobbler with tail spread, wings drooped and ruff erected.

The spruce partridge of the Northeast and the Franklyn's grouse of the West are both inhabitants of the moist spruce forests, where their dark coloration seems quite in keeping with their surroundings. The males are easily distinguished from the ruffed grouse by the absence of ruffs and by the largely black underparts. The females are much browner but have black tails with but one band of brown at the tip. Both species are known as "fool hens" because of their misplaced confidence in man. They seem to have absolutely no fear and will barely get out of one's way in the forest and will often allow themselves to be killed with a stick. For this reason they cannot compare with the ruffed grouse as game birds.



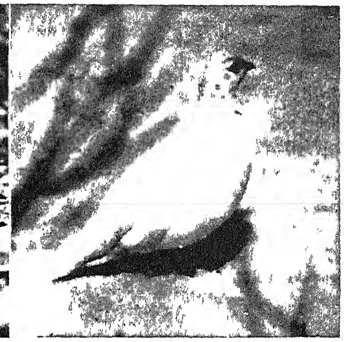
THE NEARLY EXTINCT HEATH HEN OF MARTHA'S VINEYARD

The dusky or blue grouse is found in one or another of its three forms from the mountains of Arizona to Alaska. It is considerably larger than the other grouse, of a nearly uniform bluish slate color mottled with brown on the wings. Where not hunted it is as unsuspicious as the spruce grouse, but like the ruffed grouse it soon learns to evade the hunter and makes a splendid game bird.

The prairie chickens, sharp-tailed grouse and sage grouse are birds of the open prairie or sage-brush country of the West. With the advance of agriculture into their domain, they have been pushed further and further westward and have been exterminated over a good part of their former range. The different birds, while resembling each other superficially, are quite easily distinguished: the prairie chicken by its pencils of elongated feathers on the sides of the neck and its square tail, the sharp-tailed grouse by its similar appearance but pointed tail, and the sage grouse by its large size, pointed tail and black on the underparts. All three species have interesting courtship performances in the spring which are quite different from those of the ruffed grouse. The prairie chickens, for example, assemble in small companies on knolls or open places on the prairie where the males compete for the females. Large inflatable sacs are distended on the sides of the neck to the size and color of small oranges, the stiff feathers are erected, and a loud booming sound is produced by expelling the air from the sacs. They then dance about and fight and rush at the females of their choice to win their attention.

The eastern form of the prairie chicken, called the "heath hen", formerly found throughout the coastal plain of southern New England and the Middle States, is now extinct except for a small flock rigidly protected on Martha's Vineyard.

The ptarmigan are unusual birds which become pure white in winter, their summer plumage being mottled gray and brown like the lichen-covered rocks. They are birds of the Barren Grounds, or the mountain tops above timber line, and are always associated with snow and glaciers. The only exception to this is the red grouse of Great Britain, which lives on the moors.



Photos E R Warren

MALE WHITE-TAILED PTARMIGAN (Summer plumage)

FEMALE WHITE-TAILED PTARMIGAN (Summer plumage)

WHITE-TAILED PTARMIGAN (Winter plumage)

It has the distinction of being the only ptarmigan which does not turn white in winter and is the only species of bird that is confined to the British Islands. The other European grouse are the black cock, the large capercaillie and the hazel hens.

The vanishing turkeys

Why our Thanksgiving bird bears the name of "turkey" will always be a mystery. So long ago was it christened that we can never expect to learn whether the *nom de plume* originated in some mistaken notion of the bird's native land or whether it was given it in an effort to translate its call of "turk — turk — turk" At any rate, turkey it is and always will be to the small boy with a drumstick in each hand or to the scientist who writes after it *Meleagris gallipave.*

There are two species of wild turkeys, but the second, called the "ocellated turkey", will doubtless never become of importance outside of museums because it is restricted to the peninsula of Yucatan and a small portion of the adjacent parts of Guatemala and Honduras and shows no propensities for domestication or artificial extension of its range. Nevertheless it is a beautiful bird, smaller than the common wild turkey, with purplish reflections on its back and with eyelike spots on its tail in addition to the typical bands. The body feathers are tipped with brilliant golden and coppery bronze and the head and wattles are deep blue covered with orange tubercles. In brilliancy, it is suggestive of some of the pheasants, and it even vies with the peacock in splendor.

The common wild turkey, which was originally found from Maine and southern Ontario to southern Mexico, varies to such an extent in different parts of its range that five recognizable forms or subspecies have been recognized. one from southern Mexico, one from northwestern Mexico and Colorado, one from northeastern Mexico and Texas, one from southern Florida, and the common wild turkey, found from Georgia to Maine and Ontario It is from the south Mexican that our domesticated bird is descended, the tail coverts and bands in the tail of each being gray while corresponding parts of the common wild turkey are a rich chestnut It is supposed that birds domesticated by the Indians were brought back to Europe by the conquistadors because they had become established in many parts of Europe as early as 1530. Domesticated birds were brought to North America by the colonists, and many it is believed, hybridized with the wild turkeys, as they still do where opportunity offers, until in some places where the wild turkey is still found it is rather difficult to find pure wild blood.

The wild turkey was originally an inhabitant of the open woodlands of all the Eastern States and those as far west as Kansas and Oklahoma. Today it has been exterminated in New York and New England and is confined to the rougher and more remote portions of Pennsylvania and Virginia, the larger swamps of the Southern States and thinly settled portions of the Mississippi Valley and is everywhere fast following the passenger pigeon and Carolina parroquet into history.

It is possible, however, to breed the wild turkey in captivity, and several farms for the purpose have been established The state of Pennsylvania, at least, is trying to restock its wilder game coverts with these magnificent birds and has released many obtained from the game farms.

In its habits, the wild turkey is not very different from the domestic bird. Except during the breeding season, they live in small flocks of from six to twelve individuals of both sexes, feeding upon acorns, nuts, etc., and ordinarily roosting in the same trees each night. At the beginning of the breeding season in March, the flocks disband and the males begin to gobble. Gobbling corresponds to the drumming of the grouse or the crowing of the rooster and usually is heard only early in the morning before the bird leaves the roost. When he has been successful in attracting a female, he struts and displays like the domestic bird Turkeys are polygamous, and frequently rival males engage in fierce battles, the victor becoming lord of several females After incubation begins, the males lose their animosity toward each other and again flock together, leaving the cares of the family entirely to the females.

The wild turkey is our largest and finest game bird With the increase of agriculture and the disappearance of our forests it is to be expected that its range will be greatly restricted, but as long as we have national and state forest preserves and rough country that the plow cannot turn, we should have wild turkeys Greater effort should be made by the national government and the various state conservation commissions to save the remnant of these splendid birds and to reintroduce them.

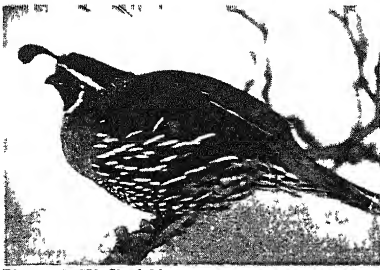
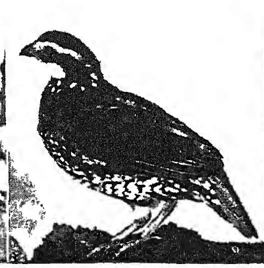
The friendly quail

At the other extreme in size from the turkeys among the upland game birds are the quails (family *Odontophoridæ*). Some of the Old World species are no larger than sparrows, and our American quails are smaller than pigeons. The American quails, of which there are about 100 species, differ from the true quails and partridges of Europe in having the cutting edge of the bill slightly serrate or finely toothed instead of smooth, and also in the entire absence of spurs on the legs. The majority of these are confined to the tropics but seven species are known north of the Mexican boundary. Of these, the bob-white is best known in the East and the California quail on the Pacific Coast

The bob-white is native as far west as Colorado but has been introduced into New Mexico, Utah, Idaho, California, Oregon and Washington. It has always been a favorite game bird and throughout the South has been fairly well able to hold its own. Of recent years, however, because of its destruction of cotton-boll weevils and other agricultural pests, a sentiment has been growing up in favor of removing it from the game list, and some states are now giving it complete protection. Its cheery call of "bob-white" is the most musical of any of the notes of the game birds, which, together with its confiding habits, is almost enough to put it on the song bird list. When hunted, however, it becomes almost as wary as the grouse, and in the many states where there are no grouse and pheasants do not seem to do well, there is nothing to take its place as a game bird.

Except during the breeding season, bob-whites are found in covies which are usually members of one family though sometimes where food is abundant the different covies join, forming large flocks. They feed about open fields, hedgerows and even gardens, and when alarmed they usually run together before taking wing and then get up with a rumble that is quite confusing. At night they form a close circle, their little tails together and their heads pointing out, a veritable bomb ready to explode at the approach of an enemy.

The bob-white is not polygamous, as are the grouse and turkeys, and the male bird is a conscientious father and helps incubate the eggs and care for the young. The nest is a mere depression in the ground beneath a fallen branch or where the dried grass is thick enough to help form the arch or roof which usually conceals the eggs from above. The ten to eighteen eggs are the whitest and most pointed of any of the gallinaceous birds.


Photos R W Shufeldt

CALIFORNIA QUAIL TEXAS BOB-WHITE CHESTNUT-BELLIED SCALED QUAIL

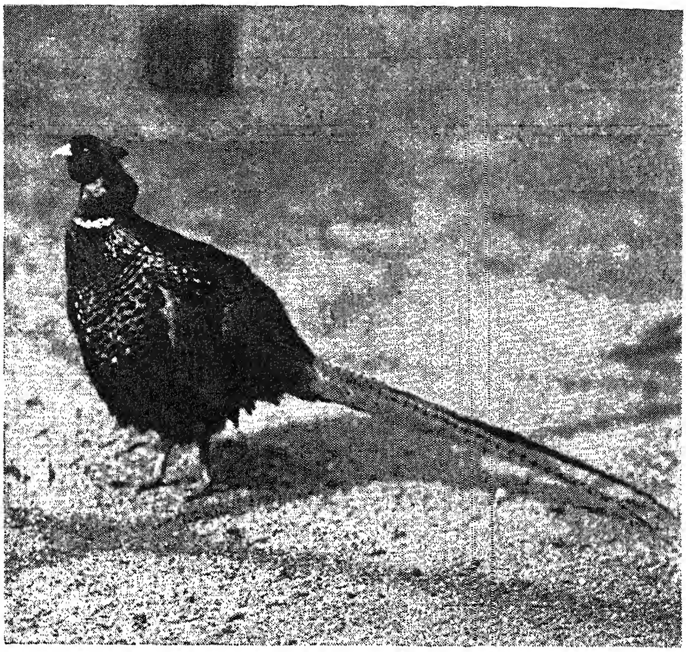
The "bob-white" call is seldom heard after the eggs are hatched, for in its place another is given that helps keep the family together. They remain together, unless scattered by hunters, until the following spring, never migrating but often moving in from the fields to the wooded bottom lands and alder thickets for the winter. The winters in New York and New England are often too severe for them, for the deep snows cover all the woods and fruit-bearing shrubs and the bob-whites have not learned to mount into the trees and live upon buds as do the grouse. The male can be distinguished from the female by the white throat and band over its eyes, the markings of the female being buff. The bob-whites of Florida are considerably smaller and those of Texas are grayer, and they have been separated into different races. In southwestern Arizona and adjacent Mexico lives the curious "masked bobwhite" with a throat that is black instead of white and with chestnut underparts.

In the Rocky Mountain region and the Pacific States, the bob-white is replaced by the California quail. It is a very different appearing bird, being bluish-gray rather than brown and having its head adorned by a few black recurved feathers that are bare at the base and swollen at the tip so as to resemble a jade ornament rather than a crest. In the interior of California and Oregon the birds are paler and grayer and have been separated into a different race and called the "valley quail". In the arid parts of the West, from Texas to Southern California, there is a quail very similar to the California quail but with chestnut flanks. It is called the "Gambell's quail". The plumed or mountain quail is a larger bird with a crest of few straight feathers. It is a shier bird, seldom coming near habitations, and preferring the open forest or chaparral growth on the mountains. As with the California quail, the birds inhabiting the humid coast region are much darker and those on the arid ridges grayer. The former is called "mountain", and the latter the "plumed partridge".

Two other quail are found in the West, the scaled partridge and the Mearn's quail. They are found in the desert country from western Texas to Arizona but the former is much the more abundant The scaled partridge, blue quail or "cotton top" as it is variously called, is gray in color, the feathers of the neck and breast edged with black, giving it a curious scaled appearance. Partially concealed on the crown is a tuft of white feathers that give it the last name. The Mearn's quail is smaller than the bob-white and has its black underparts spangled with white spots and its head striped with black and white.

All of these quail, with the possible exception of the Gambell's, have been giving way before the advance of agriculture and the ever increasing number of hunters. In spite of their great reproductive capacity, the laws regulating the open seasons and the number that can be killed will have to be stiffened to make up for the increasing number of hunters and their decreasing range. One encouraging feature is the fact that they are now being bred in captivity and each year sees the methods employed on the game farms reaching greater perfection and larger and larger numbers being raised. It is with the pheasants, however, that game farming has reached its greatest perfection and has succeeded in adding a valuable bird to the faunas of many states of the Union.

RING-NECKED PHEASANTS

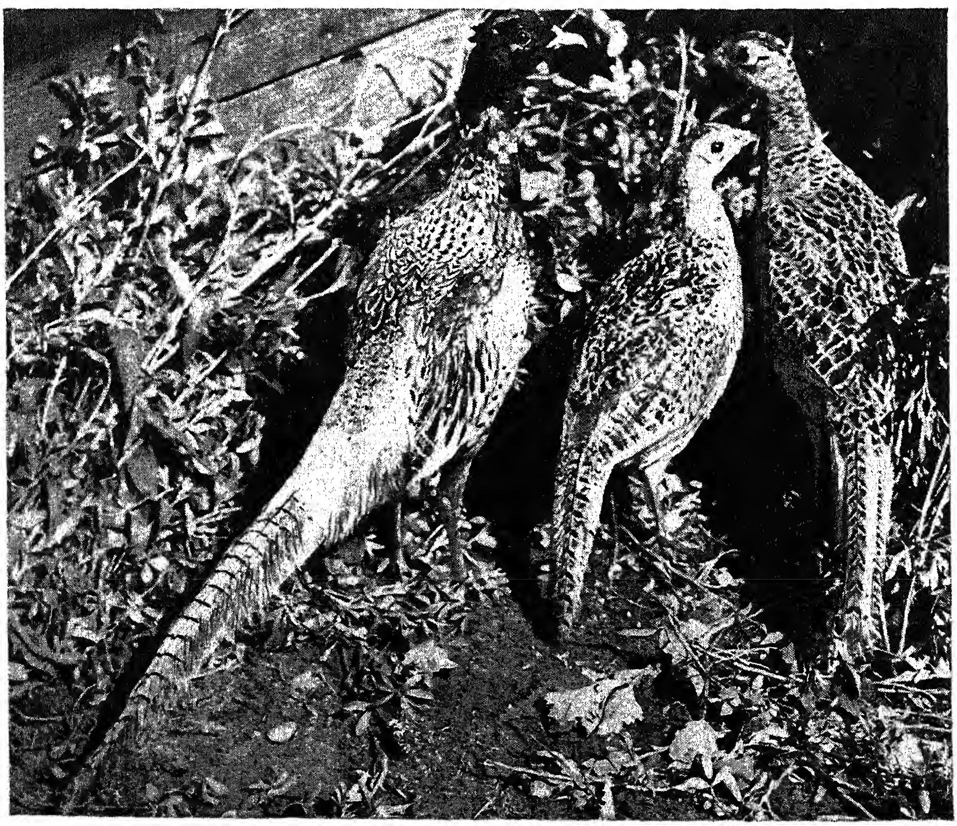


A hybrid male ring-necked pheasant. This gorgeously plumaged bird becomes shy and secretive during the hunting season.

N. Y. Zoological Society

Pheasants, like the male and two hens pictured below, are raised on game farms to replenish depleted stocks of game birds.

Frank Dufresne — U. S. Fish and Wildlife Service.



The gorgeous pheasants

There are about 100 species of true pheasants (family *Phasianidæ*) found through central and southern Asia to the Malayan region. The majority are brilliantly colored birds, though the females are dull, and many species are seen in the aviaries in this country. The resplendent golden and Lady Amherst pheasants, from western and southern China, with their wonderful capes and arched tails, are perhaps the most brilliant of all. The golden pheasant has been released in western Oregon and on Protection Island with some success, and the silver, the copper and the green pheasants also, but the only one really successfully naturalized is the ring-necked, now a member of the faunas of at least 25 states.

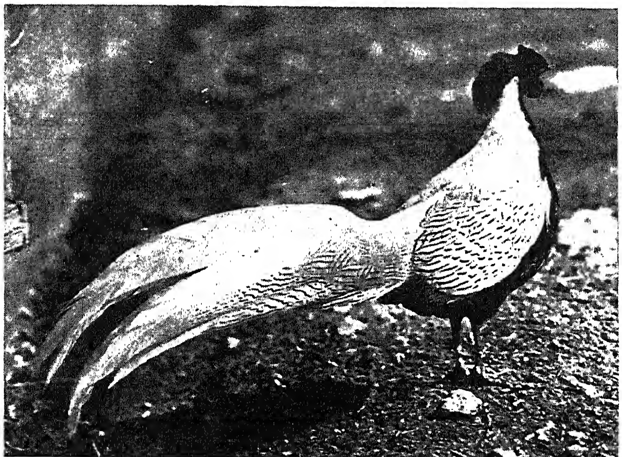
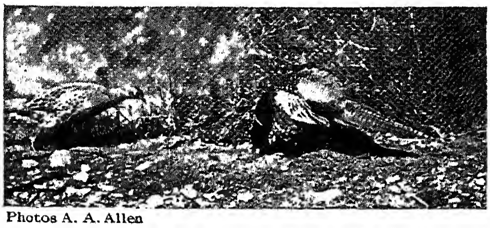


Photo A. A. Allen

MALE SILVER PHEASANT

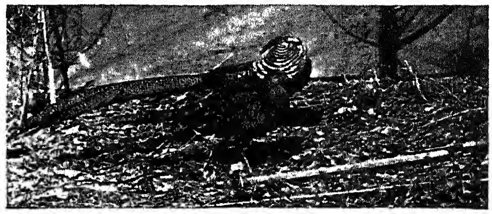
The ring-necked pheasant is not a real species but is a hybrid between the English pheasant (*Phasianus colchicus*) and the Chinese ring-neck (*P. torquatus*) and was brought over from England, where it originated. The male is a very ornamental bird with a bright metallic green head and a more or less continuous white ring around the neck. Its breast is a rich coppery chestnut, its back marked with gold and chestnut, the rump being greenish gray and the long tail banded with rich brown and buff. The female is uniformly brown spotted with darker, on the back, and were it not for her long pointed tail might be confused with the ruffed grouse.

Naturalizing a foreign bird or animal in any land is a risky undertaking as evidenced by the English sparrow and the starling in this country, which have increased far beyond control and, instead of functioning, as intended, in the destruction of insects, are rapidly replacing more valuable native birds. The naturalization of the pheasant seems to present no such difficulties, for although, when too abundant it is likely to become destructive to crops, it will always be such a valuable addition to the food supply that the slightest relaxation in the laws regulating its capture would result in its extermination. Nor is there any danger of the pheasant replacing any of our native game birds. It is a bird of the open fields and hedgerows and might in a measure compete with the bob-white except that it does not do so well in the South where the bob-white does best. In the Northern States it does not compete with the ruffed grouse because they live in different habitats, so that, all in all, it is surely a valuable addition to our upland game birds.

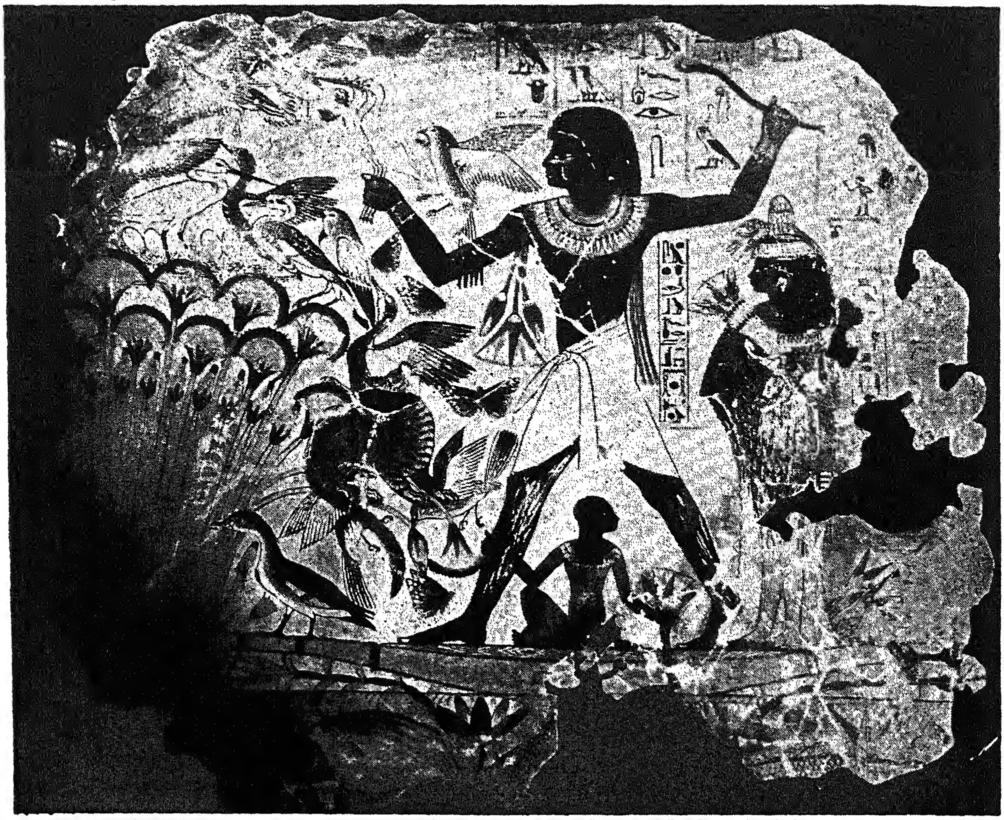


Photos A. A. Allen

RING-NECKED PHEASANT DISPLAYING TO FEMALE



GOLDEN PHEASANT DISPLAYING TO FEMALE



AN EGYPTIAN FOWLING SCENE DEPICTED ON THE WALL OF AN EGYPTIAN TOMB

MURAL PAINTING OF THE INSPECTION AND COUNTING OF A FLOCK OF GEESE IN ANCIENT EGYPT

Pictures, or hieroglyphics, were first drawn to tell a story; then the figures were condensed into symbols, and the symbols shortened into letters that formed an alphabet; and so writing began.

INTELLIGENCE AND SPEECH

How Intelligence Has Grown with the Growth of Speech, and Thought Forms Itself in Speech

THE SPEECH-CENTER OF THE BRAIN

THE study of the senses, of association, memory and attention, leads us on to intelligence, which is ultimately associated with words and speech. The intelligent man does not necessarily write or speak at any given moment, but at least he thinks, and he cannot think above the lowest level without words. Thus the process of thinking, the intelligent process, is intimately bound up with speech.

Long ago we saw that the nervous system is a sensory motor arrangement, which feels and replies. The brain itself is none other, fundamentally, than a sensory-motor mechanism; and if we study it as the organ of intelligence, we see its sensory side, above all, in terms of the hearing of speech or the seeing of written language; and its motor side in the act of speech, or in the act of writing. Nowadays, all of us who can read and write have this double mechanism, but in an earlier stage we simply have the original mechanism of hearing the sounds we call words, and reproducing them. The duplication of this primary process by means of writing and reading has had immeasurable consequences for mankind as a whole and for society. To us, here, it is simply a duplication, by eye and hand, of what we observe in the case of ear and speech organs. In any case, the whole thing is essentially one more illustration of sensory-motor action; but it utterly transcends all older forms of action, because of what the mind can do, in its deepest recesses, with those words which its senses receive and its will reproduces.

If the process were only sensory-motor, like being struck and striking, it would not detain us, but it incidentally gives the mind the incomparable instrument called language, the instrument of thought, by which it conceives, discovers, imagines, creates. We begin to see some significance in the Greek mystical use of Logos, or Word, as in the saying, "In the beginning was the Word". Words may often be feeble, foolish, empty, but they are the instrument, the indispensable instrument, and to some extent even the constructors, of thought, which is one of the supreme attributes, and is indeed the most nearly characteristic attribute, of man. As Bacon said: "Men imagine that their reason governs words, while, in fact, words react upon the understanding." We do well, therefore, to study closely the cerebral apparatus of *speech*, or *language*, words which both literally refer to what is spoken, but which may here be used as referring to words spoken and heard, written and read.

This study is as near as we shall come to intelligence, if we add it to what we have already learned about memory and association. The brain does not provide us with any special structure or "center" for thought or intelligence. We cannot point to any lobe or convolution and say "that is the thinking center". The whole brain is involved in thinking; and when we come to examine the processes of thought or intelligence we see that they can be resolved into sensation, memory, association. That, so to speak, is the dissection or anatomy of intelligence.

We cannot come upon it as a whole, in some corner of the brain, and we cannot claim for it the distinction of being something new, unprecedented, an extra, in the case of man. On the contrary, our analysis shows it to be a higher development of psychical facts, from sensation upwards, which are not peculiar to man. Any animal which can feel, remember, associate, is in some measure intelligent, which means that all animals, if not indeed all forms of life, including plants, are in some measure intelligent. The human intelligence is only the highest development of powers which are older than man. On this point all evolutionists are agreed.

Speech only a higher form of intelligent animal behavior

Further, before we study the particular kind of sensory-motor behavior, feeling and response, which we call speech, and which is so characteristic of man, let us carefully observe that this, too, is only a higher development of ways in which intelligent behavior is illustrated among the lower animals. It is, indeed, a fair question whether there is a greater gap between the powers of understanding and expression by speech seen in a highly educated dog and a simpleton respectively than between the simpleton and a man of genius or talent, in language written or spoken. We merely play with words if we say that a dog, for instance, cannot speak because it does not speak English. If an animal makes certain sounds to convey certain meanings, and if, further, it has learned those sounds, and understands the sounds, such as words, made by human beings, in all essentials that animal has some measure of the mode of intelligent behavior which we call speech when it is illustrated in man.

The difference in speech between a man and a dog a question of degree

The differences between a dog or a parrot and a man are immense and potent, but they are differences in degree, not in kind. We have a larger vocabulary, a wider range in its use, a much more efficient mechanism of larynx, lower jaw and tongue for purposes of mere articulation, and sensory organs which are capable of recognizing and remembering far more and far more minute differences in sounds or in marks on paper, but all these assertions are comparative only. We therefore approach the exact physiology of human speech with due, but with no more than due, appreciation of its remarkable place in the wide scale of nature.

Speech is essentially a sensory-motor act, as we have seen, and so we begin by reviewing the facts of its sensory aspect, which we may suppose ourselves to have studied. We have defined the visual center in the occipital lobe of the brain, and the auditory center in the temporal lobe. Presumably, then, words are seen or heard in those centers, and there is no more to learn about them. But the facts are much more complicated. It is true, and it is not true, to say that words are so seen or heard. They are there seen or heard, but they are not understood. They are seen as marks, which mean no more than, probably, Arabic writing to the reader; or heard as sounds which mean no more than Arabic words. The sheer seeing or hearing must be done in these centers or nowhere, but they do no more. If words are to be understood, if they are to mean anything, new centers must be educated. Words may be heard, remembered, repeated, as by a parrot, with a perfect sensory-motor mechanism, but that is only the imitation of intelligence, as much human speech may also be. If the process is to be true speech, truly intelligent, and capable of leading up to thought, the words seen or heard must be not only identified but understood.

The word-seeing brain-center developed by education

We find, accordingly, that there is a "word-seeing" or "word-perception" center in the brain, close to the visual center, but distinct from it. The visual center occupies the hindmost part of the cerebrum — the back of the occipital lobe. A little forward from it, only on the left side of the brain in right-handed persons, and *vice versa*, we find the "word-seeing" center, which is only developed by educa-

tion, though its capacity for such education is doubtless inborn. Here, and here alone, all words seen are understood. If it failed in your brain at this moment, on left or right side, according as you are right or left handed, and the left or right side of your brain is the "leading half", these words would still be seen as marks on paper, which you might even memorize and reproduce, but they would be just as if they were the characters of some language unknown to you. You would be what we call "word-blind". That is why we said that it is true, and not true, that words are seen in the visual center; they are seen, but they are not seen as words. It need hardly be said that this applies to the reading of music or shorthand, as well as to ordinary language.

The word-seeing brain-center characteristic of man

This fact of the existence of a separate word-seeing or symbol-understanding center — for that is what it really is — could never be discovered except by the experiments of disease. It is a fact of man alone, though it may be that highly educated, highly educable animals may sometimes develop the beginnings of such a center; and it is demonstrated in cases where a tumor, fracture, hemorrhage, arterial blockage or some other injury has chanced to throw out of action this center alone. In such cases the patient sees but does not perceive the words in front of him. We may add that the recognition of familiar faces follows the same laws, though probably a separate part of the brain, near the "visual cortex", is educated for the purpose. If the "visual cortex" itself be alone thrown out of action, of course there is an end of all vision.

The perceiving center, though entirely intact, has no material offered it for scrutiny and comprehension, for the patient is stone-blind. But if the perceiving center alone be affected, he sees the print indeed, as most of us see Arabic or Hindustani, and that is all. A similar injury in the "led half" of the brain, such as the right half in right-handed people, would produce no symptoms at all, so far as the evidence goes. It has not been educated for this special function It may be suggested, however, that the highest developments of language, in all its forms, may yet be proved to depend upon the education of the potential centers in both sides of the brain.

Forms of disease that affect the use of words

The technical name for any form of speech-failure, whether written or spoken speech, provided that it be due to the brain centers, and is not merely a defect of articulation, is *aphasia*. Mere defects of speech like stammering, or indistinct utterance due to defective action, and especially defective coördination, of the organs of articulation, do not here concern us, and should not be called aphasia, so different is their real nature. True aphasia is perhaps the highest and subtlest study in the whole range of neurology, because it brings the pure neurologist, the student of the brain and nervous action, closest to the psychologist, the student of the mind. Many large volumes have been written upon the subject; and its special significance for us here is that only the study of aphasia can reveal to us the normal physiology of speech. It is the experiments of accident and disease, some of them very rare, which have just chanced to define the respective details. They show that aphasia may take a host of different forms, and to each of these special technical names have been given. We need merely the English names; and we note, then, that what has just been described, regarding the presence of the word-understanding center, is derived from observation of cases of "word-blindness". Pure word-blindness is the description of those rare cases where this center has been thrown out of action, without any injury to the visual center or to any of its connections. In such cases, the person who could read can no longer do so, but if the words be spoken to him he knows their meanings at once. So specialized, in "cortical representation" — *i.e.*, in allocation upon the *cortex cerebri* — are the individual portions of the universally distributed whole which we call intelligence.

The curious occurrence of word-deafness from disease

Passing now to the auditory center, precisely the same facts are found. The auditory or hearing center alone hears. No hearing is possible without it, and all subsequent recognition or understanding of what is heard must first wait upon the sheer hearing. Sometimes injury or disease destroys this center, and the result is partial deafness, or stone deafness if the centers on both sides of the brain were both destroyed. If, however, this pair of centers be intact, but damage be done to a small area of the cortex close above the auditory center, on the left side only in right-handed, and on the right side only in left-handed, persons, then, though hearing will be perfect, understanding of language will be gone. If the person has learned to read, he can still read. Anything scribbled "reaches his mind" at once, for the word-seeing center is as intact as the visual center itself. But the word-hearing center is not as intact as the auditory center, and the patient is, in short, a victim of "word-deafness". This name is not, perhaps, very accurate, but it conveys the required meaning. In this instance, also, the recorded cases are rare, for an injury or disease is not likely to destroy this tiny area without touching the auditory center which lies just beneath it, but we have quite sufficient evidence to establish the facts.

Are different areas of the brain educated by different languages?

It is practically certain that distinct areas exist, or are educated, in the process of learning different languages. They are not all jumbled together; and the same is probably true of written languages and the *reading-center*, for that is what the word-perception center may be called. And now, of course, we can state, in terms of the brain, the nature of the process which we call learning to read, or learning to understand, a language. The child which gradually associates meanings with sounds, so that it understands simple, often-repeated words, is developing the potential powers of its word-perception center. It does not require teaching to see. That is an elementary, native power of the visual center, marvelously developed during months of utter darkness, which responds to the light when first the eyes open upon the world.

But the child requires teaching to read, because the association of certain sounds and certain meanings with certain designs, such as A or I, is not natural, but an artifice of man, and the child requires to form these artificial associations. Thus the central importance of association is again illustrated. We saw its importance for memory, and now we see its importance for intelligence. We have learned to associate a certain idea with the symbol I, another with the symbol O, and so on. This association is the basis of all written language. A brain of humble type cannot learn to this extent, because it has not the machinery of association. The vulture will see a letter O at a distance at which we see nothing, but its brain cannot understand the idea that O shall be pronounced as it is, and indicate what it does. That requires more than sheer vision, however acute, and depends upon the special development of a brain area which is capable of that development — the education of an educable area of the *cortex cerebri*.

Our arbitrary alphabet a growth from pictures through symbolism

No doubt there is a degree to which the association is simplified, because O suggests, perhaps, the rounded mouth which pronounces it, the widely opened eye of surprise; and just as the form of the letter is derived from the open eye, so the form of the letter I is derived from that of "man the erect". The hieroglyphics of ancient Egypt and the symbols of the modern Chinese show us the growth of a symbolic alphabet from pictures; but now, though the associations were originally natural, so that O and I suggested their meaning, perhaps, they are almost wholly arbitrary. A system of arbitrary associations — the alphabet — has been invented; learning to read means, primarily, learning the associations between forms and words. A brain capable of making such associations is an instrument of unlimited powers.

The Twentieth Century (1895-) V

by JUSTUS SCHIFFERES

SCIENCE AND TECHNOLOGY IN WORLD WAR I

THE education of military men always seems to teach them how to fight the last war over again — not how to fight the next one. World War I (1914–18) offers a striking example. It took the European generals almost completely by surprise. Their "Bible" had been the three-volume treatise by Karl von Clausewitz ON WAR — a military classic published in 1833 and based on the strategy and tactics of Napoleonic times. But advances in science and technology, applied to ordnance, explosives, communications and transportation, had caused the old ideas of warfare to be fearfully outdated. The admirals of World War I also were caught unprepared, though to a lesser extent. They had been fighting a theoretical scientific battle of armor plate for several generations. But they did not realize that the submarine would upset some of their most cherished traditions.

Of course, science and its handmaid, technology, had played a part in earlier wars. Thus, the ingenious military machines of Archimedes, based on sound mechanical principles, had dumfounded the Roman besiegers of Syracuse in the third century B.C. The introduction of gunpowder in the Middle Ages had brought about a thoroughgoing revolution in tactics; it marked the downfall of the armorclad knight as the decisive factor in battle. Later innovations — breach-loading cannon, rifles, machine guns, ironclad vessels and the like — had also brought about great changes. But in no previous war had the scientist and the engineer been so supremely important.

World War I has been called a chemists' war. This statement is an oversimplification, but there is a considerable amount of truth in it. Certainly chemists played an all-important part in insuring adequate supplies of the high explosives essential to modern warfare.

An extremely important development in the high-explosives race was the Haber process (introduced in 1909) for fixing atmospheric nitrogen. To understand the significance of this process, we must bear in mind that all explosives (except atomic bombs) contain nitrogen. This element is quite inert chemically. When combined with certain other elements, however, it is capable of violent reaction; that is why nitrogen compounds are used in explosives. These compounds are also exceedingly valuable as fertilizers; they enable plants to absorb the nitrogen that they require.

For years before the outbreak of World War I, a major source of supply for the nitrogen compounds used for explosives and in fertilizers had been the sodium-nitrate deposits in Chile. But the growing demand threatened serious shortages. Consequently scientists all over the world began to seek other sources of nitrogen compounds.

Now the air consists largely of nitrogen (something like 79 per cent by volume). If only some way could be found to fix atmospheric nitrogen in the form of suitable compounds, the problem of providing nitrogen in usable form would be solved. Several methods of fixing atmospheric nitrogen had been devised in the early part of the century; but the Haber method, perfected by the German-Jewish chemist Fritz Haber (1868–1934), was far superior to any other.

In the Haber process, hydrogen and air are introduced into massive steel chambers in which a catalyst — in this case finely divided iron — is also present. The temperature is raised to 500 degrees C.; the mixture is kept at pressures ranging up to 15,000 pounds to the square inch. The result is the forcible mating of hydrogen and nitrogen to make the nitrogen compound ammonia. With the Haber process, unlimited supplies of nitrogen compounds can be produced quite cheaply and without the use of intermediate chemicals. Haber won a Nobel Prize in 1918 for his achievement.

It has been suggested that if Haber had not developed his process, German military men would have advised against going to war in 1914. For they realized that Britain might be drawn into the struggle and that a blockade would deprive Germany of access to the Chilean nitrate deposits. But with the Haber fixation process, the Germans were assured of adequate supplies of nitrogen compounds, blockade or no blockade.

The best-known of the high explosives for which these compounds were used in World War I was TNT, or trinitrotoluene. It is made by mixing nitrogen (in the compound called nitric acid) with a colorless coal-tar product known as toluene. The German chemical industry had been based on the products of coal tar since the 1860's, and plenty of toluene was available. Germany, therefore, was well prepared for the lavish use of high explosives in World War I.

The British relied heavily upon the high explosive cordite, which has a dynamite base. Cordite could not be safely transported to the front or shot off in shells unless it had been dissolved, during the manufacturing process, in acetone. The British had derived their commercial acetone from the destructive distillation of wood. In the later stages of the war, the supply of acetone produced in this way was not adequate to meet the mounting demand. The generals faced critical shortages in high explosives; they bluntly informed the Government that another way must be found to produce acetone, or disaster would result. A Russian-born Jewish chemist, Chaim Weizmann (1874–1952), now came to the rescue.

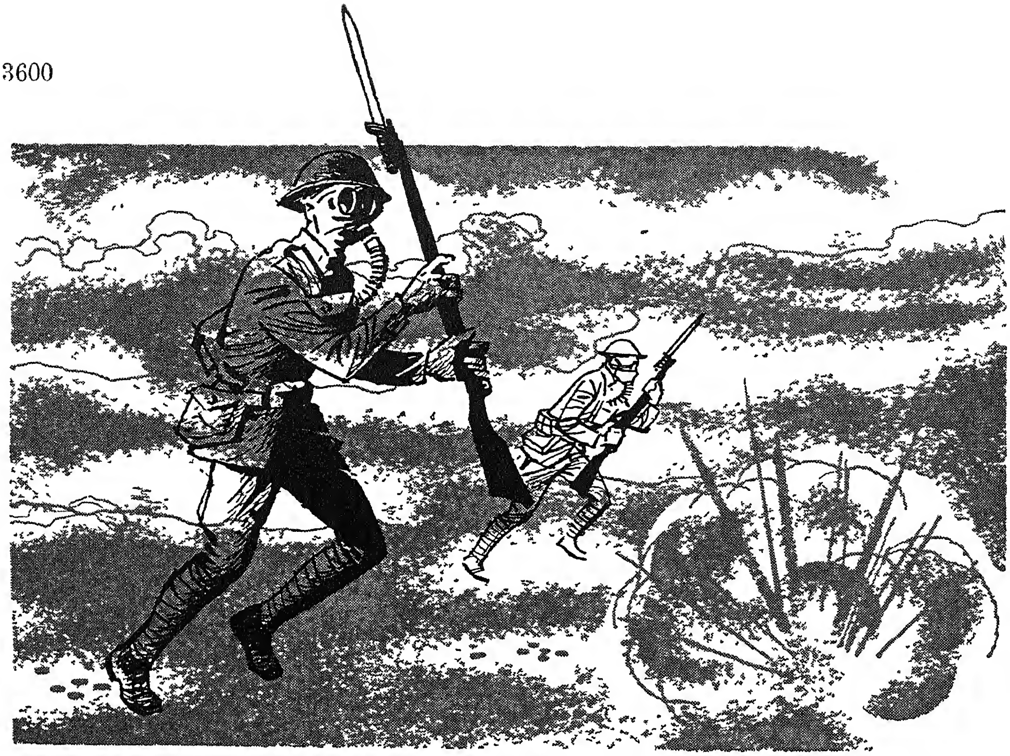
At the outbreak of World War I, Weizmann was professor of chemistry at the University of Manchester in England. He was director of the laboratories of the British Admiralty when the problem of obtaining adequate supplies of acetone was turned over to him. In the course of his chemical researches, he had tried to produce synthetic rubber; in this project he had utilized different species of bacteria. One of these, nicknamed B-Y (B for bacterium, Y for Weizmann), proved to be quite remarkable. When bacteria belonging to this species were fed on starches, such as corn syrup, they turned their foods into a variety of chemicals — including acetone. Weizmann now began to work on a practical method for producing large quantities of acetone in this way. He was brilliantly successful; soon the menace of critical shortages in high explosives for the British armies was overcome. (Weizmann later became the first president of the Republic of Israel.)

Chemical warfare in World War I

Chemists played a major role in what came to be known as chemical warfare, involving chemicals other than explosives. The most important type of chemical warfare in World War I was the use of poison gas. This dreadful weapon was first successfully employed on April 22, 1915, when the Germans sent clouds of chlorine gas, which had been stored in cylinders, against the French on the front near Langemarck, Belgium. The French troops, utterly unprotected against this type of attack, were forced back several miles. Two days later, the Germans made a similar gas attack against the Canadians in the Langemarck sector, with the same results. For some reason or other, the Germans did not follow up these successes; within a few days, the Allied troops were provided with crude gas masks, and with this protection the threat of disaster was staved off.

National Archives

Poison gases were used extensively by both sides in World War I. As the illustration shows, men and animals alike had to wear protective masks.



Next, the Germans began to fire off shells filled with tear gas. Both sides began to use these gas shells to clear trenches of hostile troops, to interfere with troop movements and to lessen the effectiveness of enemy troops by forcing them to wear gas masks for long periods of time.

The most deadly gas used during the war was mustard gas (dichlorethyl sulfide), first introduced by the Germans. Mustard gas, so called because of its smell, has only a slight odor and cannot be easily detected. It put enemy troops out of action by attacking the eyes and ears; it produced severe blisters on the flesh. Furthermore, it sometimes remained in the soil for weeks. More and more deadly gases were devised by chemists toward the close of the war. Perhaps the most terrible of all was lewisite, invented by Captain W. Lee Lewis, an American expert in chemical warfare. The war ended before lewisite was employed against the foe.

The use of poison gas is only one aspect of chemical warfare. Smoke screens were used effectively in World War I to conceal offensive and defensive movements, to cover roads and bridges and, in general, to confuse the enemy. Far more dramatic were the flame throwers, developed by the Germans. These weapons shot burning streams of oil under pressure at the foe. Though flame throwers were a terrifying weapon, they were not particularly successful in World War I; they were often apt to be as deadly to the soldiers operating them as to the foe.

German chemists sought to devise synthetic substitutes for materials that had become scarce during the war. For example, since the Allied blockade had cut down Germany's imports of natural rubber, a substitute made from methyl isoprene was used, where possible, to take its place. This synthetic rubber, which had been developed several years before the war, proved to be excellent for storage-battery cases and quite good for gas masks; but it was unsatisfactory for tires.

If World War I was, to a great extent, a war fought in chemical laboratories, it was also a war of vehicles powered by gasoline motors — lorries that took soldiers to the front lines and ambulances that brought the wounded back, to say nothing of the fleet of taxicabs that saved Paris during the first battle of the Marne by rushing reserves to the front lines. The

most dramatic use of gasoline motors was in airplanes and tanks.

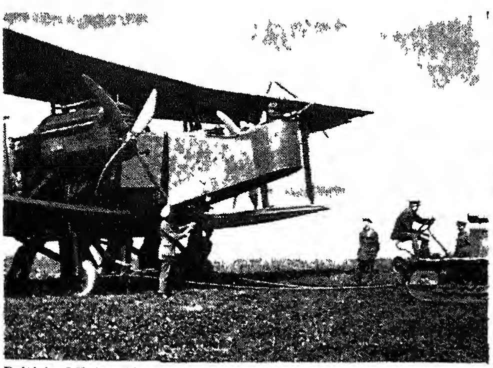
In the following section we shall tell about the development of the airplane. It was in its infancy at the outbreak of the war. At first it served chiefly to reconnoiter enemy positions and to correct artillery ranges; it was used for these purposes throughout the war. Airplane pilots shot at each other in the early days with revolvers; later, fighting planes were equipped with machine guns. Pilots were organized into squadrons, which sought to drive enemy planes from the skies. Bigger planes were used, in time, to bomb enemy positions behind the lines and enemy cities.

Lighter-than-air craft, powered by gasoline engines, also played their part in the war. Cigar-shaped, metal-framed German dirigibles, called Zeppelins (after Count Zeppelin, who devised and built them), made many raids upon English cities; they created a furor but did relatively slight damage, at least by World War II standards. The British developed a nonrigid type of dirigible, which was called a blimp; it proved useful in patrol duty over the waters of the English Channel. Captive balloons were employed by both sides to direct artillery fire.

It was the gasoline engine that made the tank, or "land battleship," an effective military weapon. These heavily armed vehicles, moving on caterpillar treads, were designed to wipe out enemy machine-gun nests and to wreak havoc in enemy trenches. The British were the first to develop tanks, which went into action as early as September 1916. It was not until November 20, 1917, however, that the land battleships won outstanding success. On that day 400 tanks made a surprise attack at Cambrai and broke through the Hindenburg line for a distance of 10 miles, taking 8,000 prisoners and 100 guns. As time went on, both sides used large numbers of tanks, including giant vehicles weighing many tons.

In the war at sea, the use of the submarine was the most revolutionary development. Though the history of the submarine goes back to the seventeenth century, the first truly practical submarine was not developed until 1899, when the American inventor John P. Holland launched his Holland No. 9. This craft had a fifty-horsepower gasoline engine for cruising on the surface. It was also provided with a storage battery; this furnished power to the electric motor that drove the ship when it was submerged. The battery was charged by the gasoline engine while the craft was on the surface. In the Holland No. 9 were incorporated most of the operating features of modern submarines.

At first the Germans used their submarines, called U-boats, only against enemy warships, but as time went on the U-boats also attacked enemy merchant ships. The Germans widened the scope of these attacks

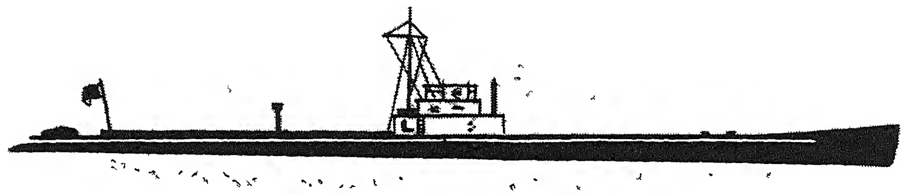


British Official Photo

Getting a large bomber of the Royal Air Force into position by means of a tractor.

National Archives

American tanks advancing in the Argonne Forest in the last year of World War I.



German U-boat, used in World War I.

until, on January 31, 1917, they announced that they would attack all shipping, enemy and neutral alike, found in certain "war zones," principally the waters around the British Isles and France. This unrestricted submarine warfare took a fearful toll of Allied and neutral shipping. Sinkings per month increased from approximately 290,000 tons in January 1917 to about 840,000 tons in April 1917. Since Britain derived a large part of her supplies from abroad, it seemed that she might be knocked out of the war.

From the very outset, the Allies had adopted certain defensive measures against submarines. The principal weapon against the submerged submarine is the depth charge, which crumbles it up by hydraulic pressure if dropped close enough to the vessel. The Allies armed their merchantmen with guns and depth charges, and sent them out in groups convoyed, or escorted, by naval craft. They hunted out submarines with a motley armada of surface ships — destroyers, sloops, motor launches, trawlers and Q-ships (decoy vessels disguised as tramp steamers). They used airplanes and blimps to spot U-boats. They also developed a device called a hydrophone, which made it possible to hear at a considerable distance the noise made by a submerged submarine. After the United States entered the war in April 1917, her immense industrial resources were used to bolster up the antisubmarine campaign. At last the U-boats ceased to be a major menace.

Science and technology were not the only decisive factors in World War I. Allied victory was made possible also because ragged infantry in muddy trenches held back the German hordes; because the Allied blockade was effective; because the soldiers and the civilian populations of the Central Powers lost the will to resist. But even the most reactionary military men had to acknowledge that something new had been added to warfare — that in any future war scientists and engineers would play an all-important part.

THE COMING OF THE AIR AGE

The dream of flying "like the birds" goes back to antiquity, as the Greek legend of Daedalus and Icarus attests. Before the outbreak of World War I, man had conquered the air in the sense that he could take off and remain aloft for minutes and even hours at a time. But this conquest was a modest one indeed. Flying machines consisted of slow and unwieldy dirigibles, erratic free balloons and flimsy heavier-than-air "crates" of canvas and wire, propelled by feeble gasoline engines.

By the end of World War I, the picture had completely changed. Under the spur of military necessity, the production of airplanes had soared. New models had been constantly developed, only to be discarded for still more efficient models. Formerly an unreliable novelty, the airplane had become a sound flying machine.

It had completely outdistanced its lighter-than-air rivals. Today, blimps are used to a small extent for advertising purposes; in warfare they serve for antisub-

marine patrol. Free balloons play a part in weather research and in the study of the upper atmosphere. Big dirigibles may stage a comeback some day. But our modern air age is based almost exclusively on heavier-than-air craft.

The air age was ushered in, unheralded, on December 17, 1903, on the windswept beach near Kitty Hawk, North Carolina. On that historic day, two American bicycle-builders, Orville (1871–1948) and Wilbur (1867–1912) Wright, succeeded in launching their motor-powered, man-carrying biplane, or two-winged airplane. The first flight, in which the plane was flown by Orville, lasted only 12 seconds and the plane traveled just about 120 feet. Later that day, the two brothers, taking turns at the controls, made three more short "hops." Thereupon, they quietly packed up their plane and returned to their home town of Dayton, Ohio, in order to spend the Christmas holidays there.

This epoch-making flight climaxed centuries of dreaming, hoping and striving. Legendary accounts of human flight abound in ancient literature. In the sixteenth century Leonardo da Vinci drew up plans for a flying machine called an ornithopter; it had flapping wings that were to be operated by hand. In the eighteenth century, daring aeronauts, like the Montgolfier brothers, left the ground in balloons and entrusted themselves to the winds.

Aeronautical pioneers of the nineteenth century

During the nineteenth century, men sought to master the principles of flight. A few names may be mentioned here. The German aeronautical engineer Otto Lilienthal (1848–96) built many gliders; he was killed while flying one of them. Octave Chanute (1832–1910), born in France, came to the United States as a boy of eight and made a great reputation as a civil engineer. A keen student, he worked out and published many aerodynamic tables and eventually designed a two-wing glider, which was exceptionally stable in flight. The Wright brothers freely acknowledged his influence on their work.

Samuel P. Langley (1834–1906) risked his scientific reputation to make important contributions to the science of aerodynamics. A self-taught scientist, he became a renowned astronomer and physicist and secretary of the Smithsonian Institution in Washington, D. C. He was particularly interested in the possibilities of flight in powered planes and he obtained grants from the United States Congress in order to carry on his experiments. On May 6, 1896, his nine-pound, steam-driven model Aerodrome No. 5, launched from a houseboat on the Potomac River, soared into the air, flew half a mile and landed without mishap. This was the first successful flight of a powered motor airplane. Alexander Graham Bell, inventor of the telephone and a personal friend of Langley's, took photographs of the unheralded but epoch-making flight.

Langley next constructed a full-size plane, for which his assistant, Charles Manley, built a five-cylinder gasoline motor. On December 8, 1903, the new craft was hoisted to the roof of a houseboat on the Potomac; Langley and Manley got into it and Manley took the controls. The plane was then catapulted from the houseboat — and plunged unceremoniously into the chill waters of the Potomac. Nine days later the successful flight of the Wright brothers took place.

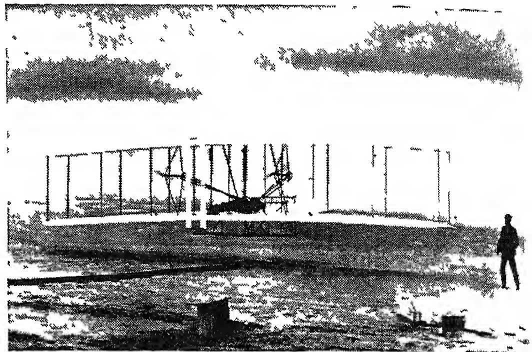
In one way, the Kitty Hawk flight marked a climax, but in a very real sense it was only a beginning. People refused at first to take the Wrights seriously; in fact, many believed that the Kitty Hawk flight was an elaborate hoax. It was not until the Wright brothers made a number of successful flights in England that the public at large began to take notice. By 1908, the Wrights' planes could fly a distance of 100 miles at a speed of 40 miles an hour. Other air-age pioneers built planes of their own. Some of these were biplanes, like those of the Wright brothers; others were triplanes, with three wings; still others were monoplanes, with but one wing.

On July 25, 1909, the French aviator Louis Blériot startled the world by crossing the English Channel in a small monoplane

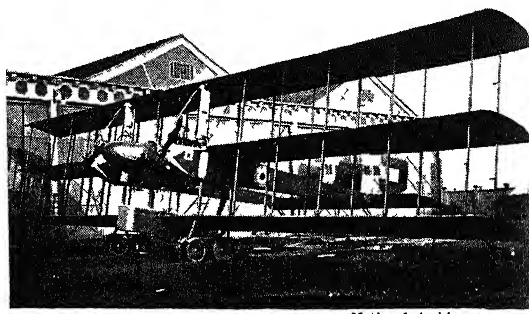
that he had designed and built; he covered the twenty-one miles in thirty-seven minutes. Forward-looking military men began to sense the potential importance of the plane. One government after another began to subsidize aerodynamic research and airplane manufacture.

As we have pointed out, the airplane came of age in the course of World War I. Two brilliant flights soon after the end of the war showed how much had been accomplished. In May 1919 the United States flying boat NC-4 flew from New York to Plymouth, England, by way of the Azores and Lisbon, Portugal. The first nonstop flight across the Atlantic took place in June of the same year. Two English officers, Captain John W. Alcock and Lieutenant Arthur W. Brown, took off from St. John's, Newfoundland, and landed in Clifden, Ireland.

In the years that followed, progress was steady: aviators, manufacturers, engineers and research scientists all contributed to the improvement of the airplane. Air-transportation companies scheduled passenger flights; regular air-mail service was established. The growth of the airplane industry was highlighted in the late 1920's by a series of dramatic flights. On May 20, 1927, a young American aviator, Charles A. Lindbergh, took off in a solo flight from Roosevelt field, near New York City; thirty-two hours and twenty minutes later, he brought his plane down at the Bourget Airport near Paris, France. In the years that followed, there were a number of other notable flights; the Atlantic and the Pacific were crossed again and again. By this time passenger flights had become a commonplace. Freight planes began to open up new areas to commerce.


Smithsonian Institution

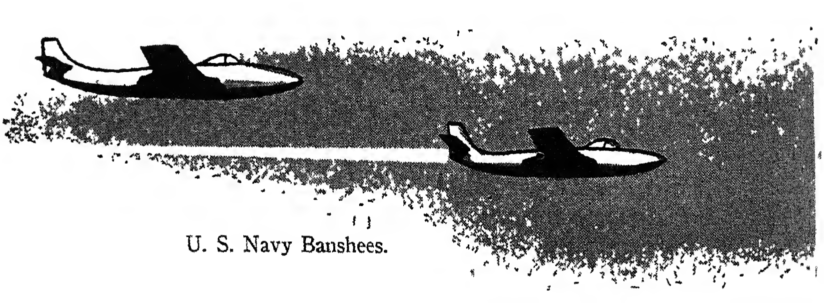
The historic flight of the Wright brothers' biplane at Kitty Hawk, in North Carolina, December 17, 1903.


National Archives

The triplane shown above was an early type of flying craft. It proved cumbersome in flight and was discarded.

The military services of the world built up big air fleets. Most of these were land-based; a certain number of planes took off from the decks of huge airplane carriers.

Many of the improvements in airplane design were brought about by aerodynamic research in wind tunnels. These consist of tunnel-like passages, through which air is blown at known velocities in order to determine the action of wind pressure on full-


U. S. Navy Banshees.

scale airplanes or on airplane models. For example, wind-tunnel researches showed that the landing gear of an airplane greatly reduced its speed. Aeronautical engineers, therefore, designed retractable gear; now many planes, like birds in flight, can "tuck in their feet."

In World War II, as we shall see in a later chapter, the airplane was no longer a valuable supplementary weapon; it was a major arm of the military services. Without the airplane, World War II would have been an entirely different sort of war, and it might have ended differently.

The war saw the launching of a new type of flying machine — the jet plane. In this type of aircraft, air is drawn into the engine; it is compressed, fuel is injected into it and the mixture is ignited. The hot gases that are formed are compressed and then ejected through a nozzle at the rear of the plane. The reaction produced by escaping jets of hot gases furnishes the motive force that drives the plane forward. The idea is not new; old-fashioned skyrockets are propelled into the air on the same principle.

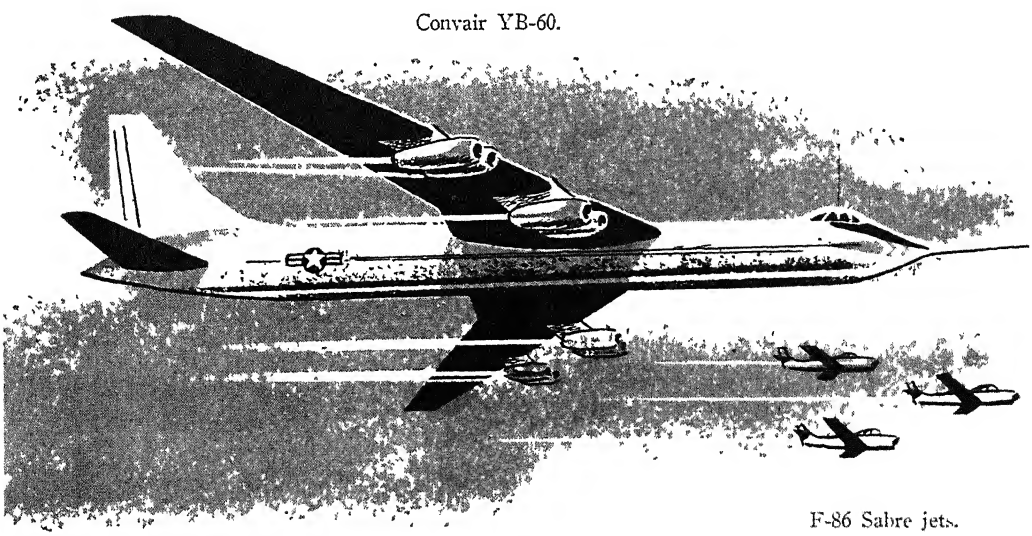
The jet plane was suggested in the year 1928, when a young English flight cadet, Frank Whittle, wrote a thesis on the future development of airplanes; in this paper he set forth the idea of jet propulsion. Whittle took out a patent for a jet-propelled machine in 1930, but found no backers at first. The Royal Air Force became interested in the project after a time, however, and it was carried forward energetically. The first successful jet motor was built in 1937, but it was not until May 14, 1941, that the first British jet plane took to the air.

It was the Germans who used jet-propelled planes most effectively in World War II. They loaded crewless jet planes with high explosives and launched them from sites on the west European coast in the general direction of London. The planes, which were called V-1's, flew until their fuel was exhausted; then they dived to earth and exploded. The Germans also put a few jet pursuit planes into the air toward the end of the war; they outsped their foes but did no particular damage.

World War II also marked the development of the rocket as a flying machine capable of sustained flight. The Germans created the V-2, a huge rocket, over 145 feet long and weighing over 12 tons. Launched from the Dutch coast, V-2's reached an altitude of 65 miles and traveled a horizontal distance of 200 miles before they plummeted to earth and exploded.

After the war, both jet planes and rockets were greatly improved. The flight

Convair YB-60.



F-86 Sabre jets.


U. S. Navy photo

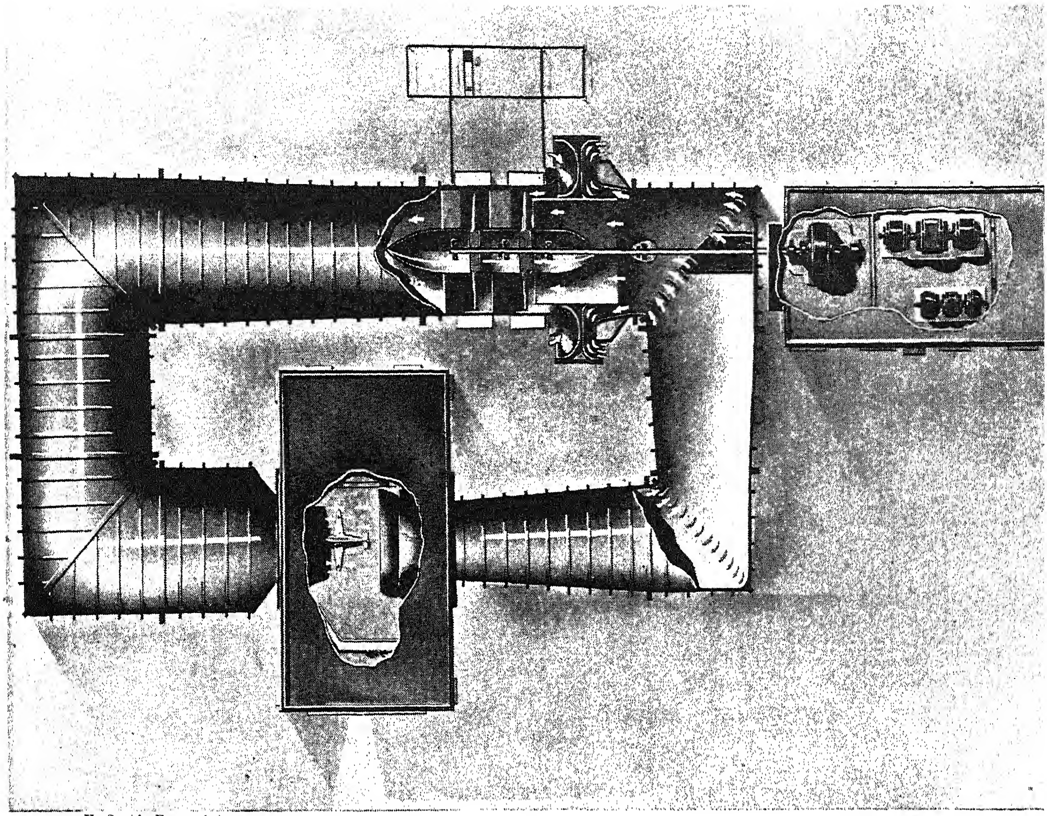
Helicopter in flight. The helicopter is the most versatile of aircraft; it can take off and land vertically and hover in the air.

range and speed of jet planes were increased and the craft were made more maneuverable. The air arms of the world began to build up fleets of jet pursuit planes and bombers; jet transport planes were also developed.

The range of rockets was greatly increased; rockets were sent hurtling more than a hundred miles into the upper air. A few scientists and engineers have begun to talk about using rockets for interplanetary flight; but, thus far, flights into outer space are still in the realm of wishful thinking and science fiction. As a matter of fact, rockets are the only aircraft developed thus far that could be employed for flight "out of this world," should it be achieved. This is why. The air thins out rapidly above the earth; at the height of seventy miles, there is more of a vacuum than could be produced in a laboratory. A propellered craft could never fly here, since it remains aloft because its propeller reacts against air. As for jet planes, their fuel can burn only when it is mixed with oxygen from the outer air. But a rocket carries within itself the oxygen that is necessary for combustion, and hence it is entirely independent of atmospheric oxygen.

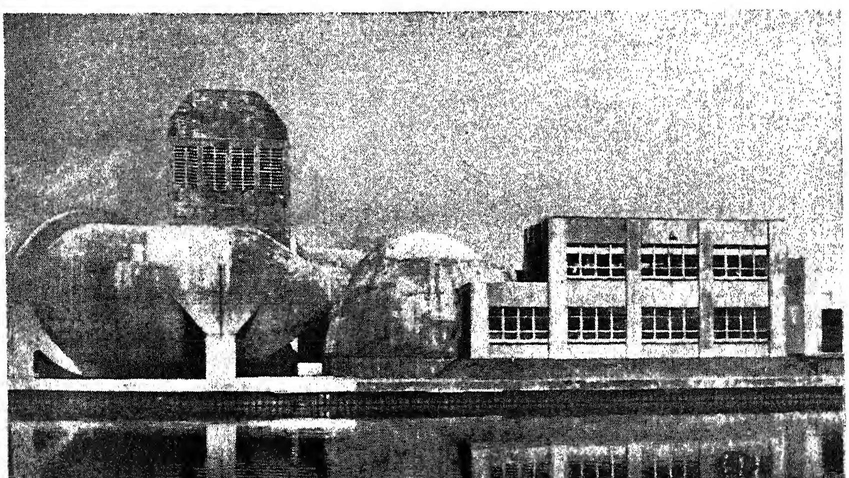
The period following the end of World War II saw the development of the helicopter as a practical flying craft which can fly slowly, land vertically and hover in the air. In this craft, the propeller is replaced by huge rotary wings, which whirl above the fuselage. Sometimes there are two sets of these horizontal rotors; sometimes a second rotor, turning on a horizontal axis, is set at the tail. The helicopter represents an improved version of the Autogiro, invented by the Spaniard Juan de la Cierva and first flown successfully in 1928. Many pioneers in the field of aeronautics worked to perfect the helicopter; among them were the German Heinrich Focke, the Frenchman Louis-Charles Bréguet and the Russian-American Igor I. Sikorsky. Before the outbreak of World War II, these men had developed helicopters that could fly; but it was not until several years after the war that these odd-looking flying craft became really effective.

The great advantage of the helicopter lies in its maneuverability. It can take off and land vertically and at very low speeds; it can hover over the same place indefinitely. It has been used to carry air mail from the roofs of central postoffices to waiting airplanes, to take off persons from disabled craft or lifeboats at sea, to rescue flyers who have been forced to bail out behind enemy lines. Some aviation engineers believe that the helicopter will be the favorite private aircraft of the future.



U. S. Air Force photo

Diagram of a wind tunnel (viewed from above) at the Wright-Patterson Air Force Base, Dayton, Ohio. The arrows show the direction of the air stream. In the diagram we see the motors, the drive shaft and the two forty-foot fans.



Nat. Adv. Com. for Aeronautics

Wind tunnel built for the National Advisory Committee for Aeronautics at Langley Field, Virginia. The tunnel is used for research on large-scale models and full-size airplane parts at speeds that range up to 500 miles per hour.

The airplane has not made the automobile, the railroad train and the steamship obsolete; but it has become indispensable in our modern civilization. It provides swift passenger transportation, linking together the countries of the world by a maze of air lines. Air freight has opened up new sources of raw materials for the world's industries; it has made possible long-range hauling of livestock and of perishable foods. The airplane has served to control insect pests by spraying crops with insecticides It has surveyed accurately and quickly vast areas of the world's surface. Photographs taken from the air have been combined to make magnificent relief maps. The airplane is also, unfortunately, a frightfully effective weapon in warfare, particularly since the atomic bomb has become a grim reality. These two weapons have raised the question whether science and technology will destroy civilization.

EXPLORING THE DEPTHS AND THE HEIGHTS

The airplane has made the exploration of the surface of the globe almost too easy. The North and South Poles, once the goal of earthbound explorers, have been reached with little trouble by airplanes; flights over the North Pole have become a perfectly routine affair. Inaccessible regions have been mapped from airplanes equipped with cameras or with the electronic device called shoran. Only a century ago, vast land areas on our planet were represented only by blank spaces on maps; today such blank spaces are being filled rapidly.

Yet there will be abundant scope for explorers for ages to come, for the ocean depths, the atmosphere and the skies are still full of mystery. In the twentieth century, many efforts have been made to lift the veil. Men have gone down into the sea in bathyspheres and benthoscopes and have mapped the depths with sonic equipment; they have sent balloons, planes and guided missiles into the stratosphere; they have peered into the heavens with more and more powerful telescopes. Here we shall note briefly what they have accomplished.

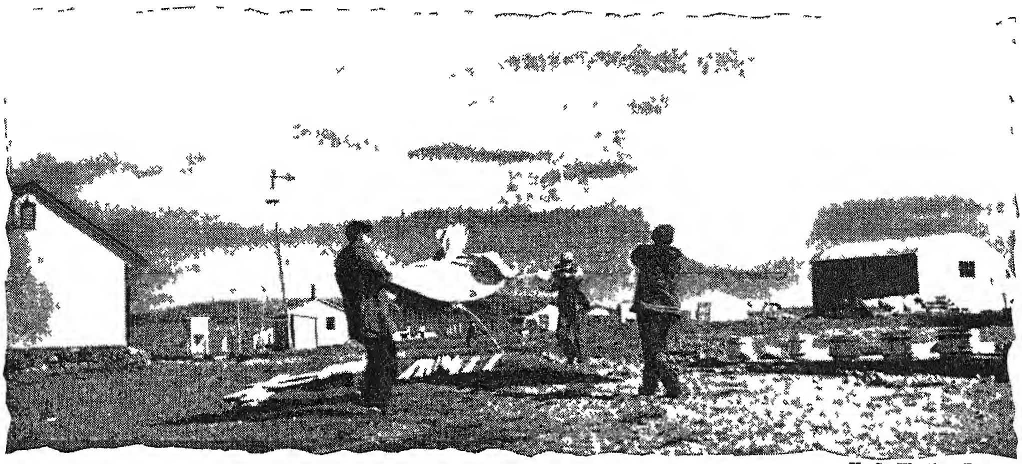
Man's knowledge of the oceans, which cover some three-quarters of the earth's surface, was surprisingly meager until comparatively recent times, and much of it was based on misconceptions. For example, until the third decade of the twentieth century, the general belief was that the floor of the deep ocean was a flat plain. After World War I, these ideas were radically revised, chiefly because of a new and revolutionary type of sounding, called echo sounding — an entirely appropriate name.

In echo sounding, a plate on the bottom of a vessel is tapped, and sound waves move away in all directions. Upon reaching the bottom, they bounce back as echoes and are received in a hydrophone installed in the bottom of the vessel. By measuring the elapsed time, a record can be made of the depth of water at a particular place. The old method of sounding by lowering a weight to the sea bottom was painfully slow; almost a whole day was required to make a single sounding of a depth of two or three miles. In the same period of time, the sonic method would provide thousands of readings.

The data supplied by echo sounding has shown that the ocean floor is as uneven as the surface of the land. There are high mountains; there are great depths, which compare with Death Valley and the great Rift Valley in eastern Africa. There are submarine canyons, comparable to the largest that are known on land. There are fiords and shelves off the coast; there are great trenches.

We know today that life teems at all levels of the ocean depths and that major groups of marine animals are represented there. We have come to realize, also, that this marine life, with a few exceptions, is dependent directly or indirectly upon the minute plant life on or near the surface of the water — the phytoplankton, as it is called by botanists.

The strange life in the ocean depths has been studied in the present century by means of a scientific device called the bathysphere, developed by Charles William



The radiosonde is a small automatic weather station, equipped with a radio transmitter. Carried aloft by an unmanned balloon, it sends weather data to ground stations

Beebe in 1930. The bathysphere is a heavy steel ball, fitted with quartz windows. It is lowered into the ocean from a ship by means of steel cables attached to a crane. Telephone communication and electric current are provided through insulated wires running from the ship to the bathysphere; the air within it is kept fresh by means of oxygen tanks. The bathysphere has reached depths greater than 3,000 feet. Another type of diving sphere — the benthoscope, pictured on page 828 — has penetrated even farther into the ocean depths; it has already gone down a distance of 4,500 feet.

The atmosphere above us has also been the subject of intensive study in recent years. Scientists have succeeded in estimating its height by analyzing (1) the duration of twilight (twilight depends on scattered sunlight from particles in the upper atmosphere); (2) the height at which meteors become luminous; and (3) auroral streamers. They have come to the conclusion that atmospheric gases, thinning out as distance above the earth increases, extend to something like four hundred miles above the surface of the earth. They have also analyzed the layers into which the atmosphere is divided.

The study of the atmosphere has brought about remarkable advances in meteorology. Among other things, Norwegian weathermen developed a new way of making weather forecasts by means of air-mass analysis. A few nineteenth-century meteorologists had suggested that the weather at ground level was really being made in the higher levels of the atmosphere. It was not, however, until the year 1918 that these speculations were ably demonstrated and scientifically proved by the Norwegian meteorologist Jakob Aall Bonnevie Bjerknes (born in 1897). He made a careful study of the isobaric lines (showing the places where the atmospheric pressure is the same) in huge series of weather maps. It eventually occurred to him that changes in the isobaric lines, at least in the Northern Hemisphere of the globe, were actually caused by the expansion and contraction of the huge polar air mass that always hangs over the North Pole.

Today weather forecasts are based largely on the analysis of the advancing or receding masses of air, called "cold fronts" and "warm fronts." Weathermen take air soundings of these masses, which lie high above the earth's surface. The key instrument in these soundings is the radiosonde, a small automatic weather station which floats aloft on a balloon. It is equipped with a tiny radio transmitter which sends back signals to the ground stations; these signals record the temperature and moisture content of the air masses above. The data obtained from air soundings is rapidly communicated by radio and telegraph to weather stations throughout the world.

From this information, meteorologists are able to draw up weather maps and to make weather predictions.

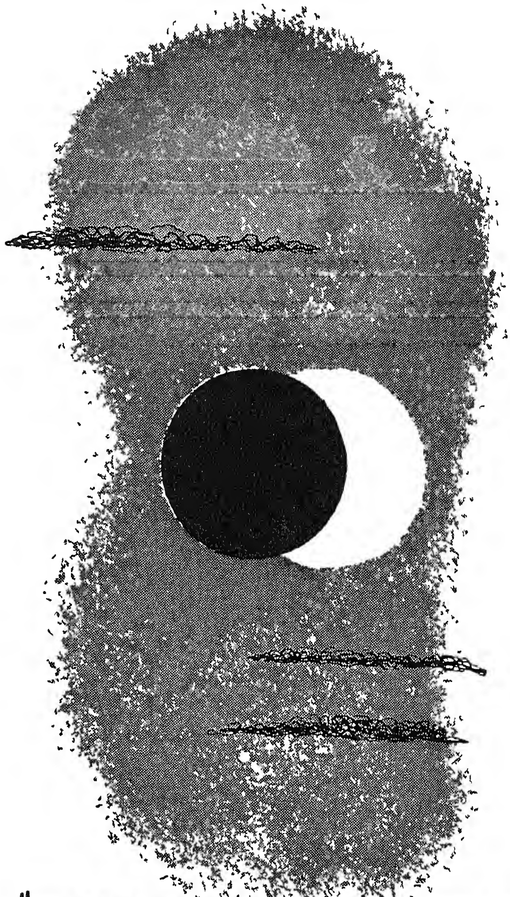
The exploration of the skies has also made great progress in recent years. With his marvelous instruments — the telescope, the spectroscope, the spectroheliograph, the photometer, the bolometer, the photoelectric cell, the thermocouple — the astronomer cannot only peer far out into space but he can analyze the composition of the heavenly bodies.

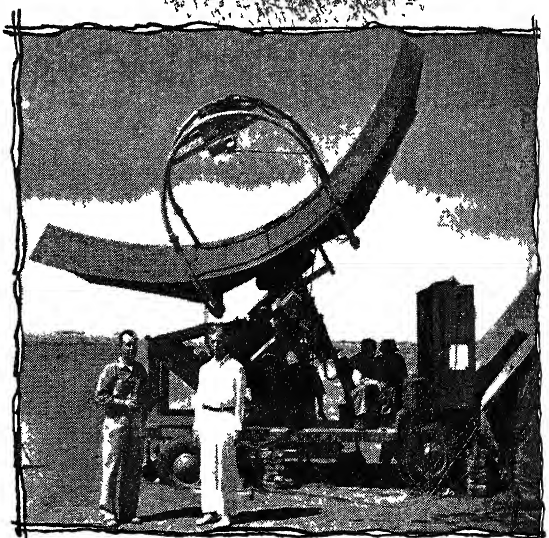
Perhaps the most famous of the astronomical instruments perfected in the twentieth century is the 200-inch telescope erected in 1948 at Palomar Mountain in California. This "Glass Giant of Palomar" has widened greatly the observable region of the heavens. The biggest telescopes previously used could not photograph celestial objects beyond a distance of 500,000,000 light-years. (A light-year is about 6,000,000,000,000 miles) With the 200-inch telescope, astronomers have photographed a galaxy 1,000,000,000 light-years away.

A new theory concerning the origin of the sun's energy

The sun has been the object of intensive investigation. An entirely new theory of the origin of the sun's energy was advanced in the twentieth century. In 1929, Robert d'Escourt Atkinson and F. G. Houtermans had suggested that energy might be liberated in the stars as a result of nuclear transformation, involving some of the lighter atoms. Ten years later, Hans A. Bethe (born in 1906), a German-born physicist teaching at Cornell University, advanced his carbon-cycle theory of the source of the sun's radiation. According to this theory, solar energy is generated by a six-step reaction, in which four atoms of hydrogen are turned into an atom of helium with the help of an atom of carbon, which remains unchanged during the process. It is now believed that this hydrogen-helium reaction is responsible for generating energy in most of the stars.

We have come to realize that all stars emit a variety of radiations, called electromagnetic waves. (We discuss electromag-





U. S. Navy photo

The radio telescope that is shown in the above photograph was set up on a plain not far from the city of Khartoum, in the Sudan, in order to study the sun during a total eclipse.

netic waves in Science and Progress III, Volume 6.) Certain stars produce the electromagnetic radiations known as light waves; these heavenly bodies are visible, either to the naked eye or through the medium of the telescope. Other stars emit radio waves, which can be picked up in special radio receivers, known as radio telescopes. (Certain stars, like our sun, produce both light waves and other electromagnetic waves.) The study of radio waves originating in celestial bodies has given rise to a new branch of astronomy called radio astronomy. Its beginnings go back to the year 1932, when Karl G. Jansky, of the Bell Telephone Laboratories staff, began to investigate certain mysterious sounds that spoiled radio reception.

The study of radio waves originating in space has revealed the presence of something like a hundred huge invisible bodies in the Milky Way. We know very little about these bodies, which have received the appropriate name of radio stars.

A ninth planet is discovered

The twentieth century saw the discovery of a new planet, bringing the number of known planets to nine. In 1905, the American astronomer Percival Lowell (1855–1916) deduced the existence of this new planet, which he called Planet X and whose orbit he set beyond that of Uranus. He sought unsuccessfully to find Planet X in the skies. It was not until 1930 that it was finally spotted by Clyde W. Tombaugh, a member of the staff of the Lowell Observatory, at Flagstaff, Arizona. It was named Pluto in honor of the Greek god of the underworld.

A fascinating doctrine that has had its ups and downs in the present century is that of the expanding universe. The doctrine is based on the fact that when we photograph the spectrum of a galaxy, the lines in the spectrum are shifted toward its red end, as compared with their normal position. The explanation given heretofore is that this redward shift is caused because the galaxies are moving away from us. The farther away the galaxies are, the more rapidly they seem to be receding. Within recent years, however, the suspicion has grown that the redward shift is due to some other factor.

Various theories of the origin of the heavens have been proposed in the twentieth century. In the first years of the century, the astronomer Forest Ray Moulton (1872–1952) and the geologist T. C. Chamberlin (1843–1928), of the University of Chicago, proposed what became known as the planetesimal theory of the origin of our universe. According to this theory, the sun collided or nearly collided, eons ago, with another star. The gravitational attraction of the other star caused great masses of gases to be pulled out from the sun. These masses kept whirling around, changed into liquids as they cooled and gradually became small solid masses — planetesimals. Eventually the planetesimals drew together to form the planets.

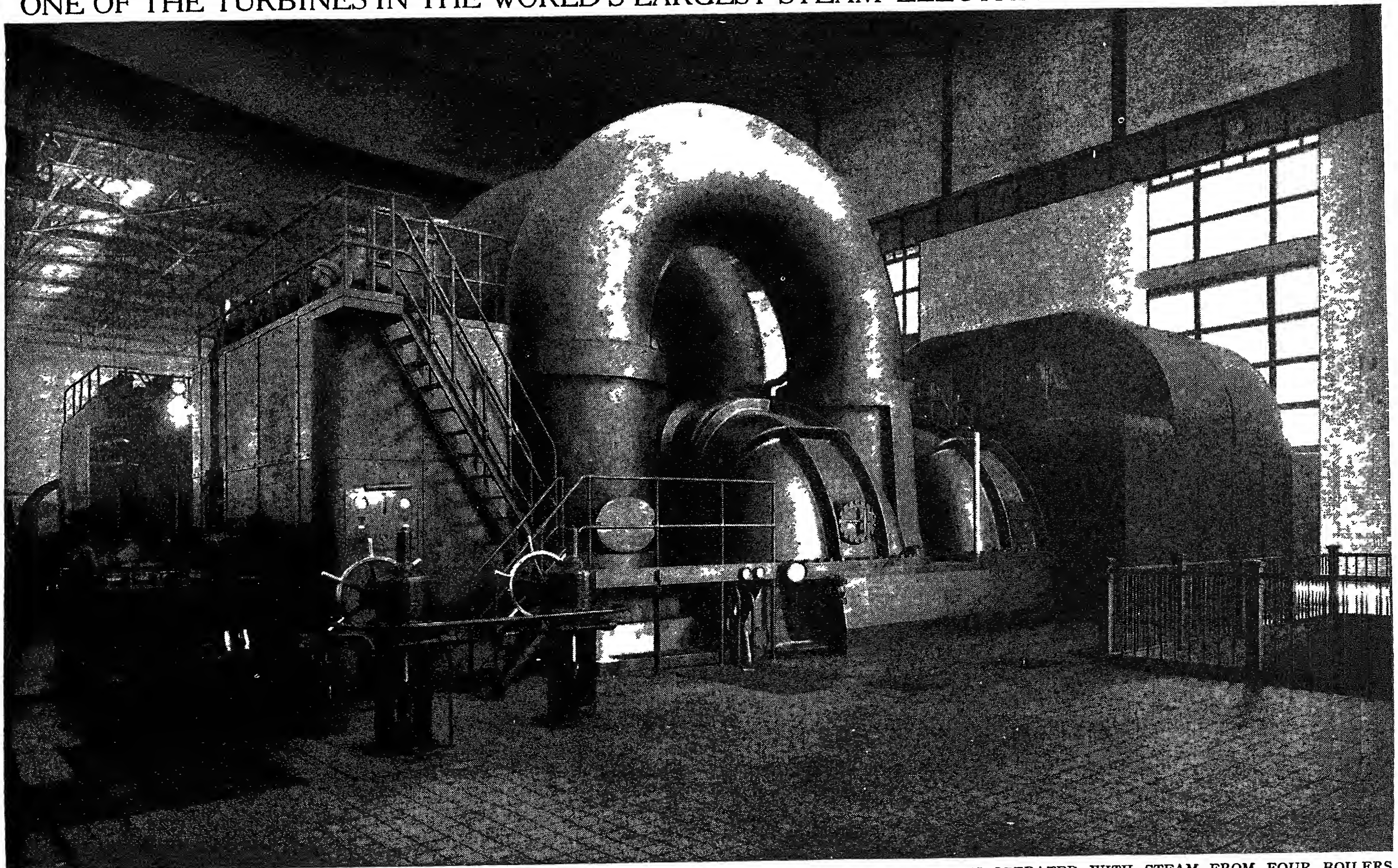
The English astronomers Sir James H. Jeans and Harold Jeffreys proposed a variation of the planetesimal theory. They retained the idea of a collision between the sun and another star. They held, however, that the planets were formed from the original masses of gases pulled out of the sun by the star, and not by the building up of large planets from small particles.

A dust-cloud hypothesis was proposed by Dr. Fred L. Whipple (born in 1906) of Harvard University. He believed that the planets were derived from streams of dust particles, which moved through a massive dust cloud. These particles began to spiral toward the center of the big cloud; as they did so, they began to form new clouds within the original one. Whipple held that in time some of the smaller dust clouds began to revolve about the central point of the big cloud; these became the planets. Other small clouds reached the center of the big one; they all merged into a single mass and became the sun.

Still other theories of the origin of the universe have been proposed; but none has been definitely proved or widely accepted. The origin of our universe remains as baffling a mystery as ever.

SCIENCE THROUGH THE AGES is continued on page 3665.

ONE OF THE TURBINES IN THE WORLD'S LARGEST STEAM-ELECTRIC GENERATING PLANT



THIS TURBINE OF THE CONSOLIDATED EDISON SYSTEM OF N. Y. HAS A CAPACITY OF 215,000 HORSEPOWER AND IS OPERATED WITH STEAM FROM FOUR BOILERS

THE ELECTRIC AGE

The Leading Part That Electricity Plays in Modern Civilization

THE UNIVERSAL SERVANT OF MANKIND

AT some time or other, every youthful reader of the Arabian Nights has doubtless been possessed with the vain hope that he might some day find Aladdin's wonderful lamp, and by rubbing it cause an all-powerful genie to appear, exclaiming, "What do you desire? I am ready to obey you as your slave." Maturer minds during the past century have perhaps discovered the lost lamp in a new form; a rival, at least, of Aladdin's genie has materialized to serve the commands of all civilized nations. The modern genie is called "electricity", and he is instantly summoned, ready to undertake the tasks of all those who turn an electric switch or push a button. Scientific discovery has thus transmuted fiction into fact, and has fettered the new slave so completely that he can never escape.

The use of electricity has become so closely interwoven with modern life and we have become so accustomed to its influence that its effect upon the existing state of civilization cannot be easily estimated. One of the first achievements of electricity was that of abridging space. A century ago, war might have broken out in Europe without becoming known to the inhabitants of the United States for weeks, perhaps months. The telegraphic transmission of intelligence through our ocean cables makes the daily news of London, of Paris and of Berlin appear almost simultaneously in New York, in Chicago or in San Francisco. Electricity has thus cemented the bonds of international interest and uprooted the physical barriers which fomented discord and misunderstanding between nations. International trade, as well as diplomatic intercourse, has been negotiated as easily as between neighboring cities. The wireless telegraph has, moreover, not only connected continent with continent but united every ship at sea with either continent and with every other ship at sea. The land line, the ocean cable and the wireless telegraph have brought the whole world to our door; the thoughts of an individual may be flashed into every town and hamlet, and the response returned as quickly.

Prior to 1876, conversation between individuals living miles apart was impossible. It was necessary for one to travel the intervening distance to place himself in the presence of another before a conversation could be carried on. The telephone has bridged this distance so that we may converse at length with a person located anywhere within reach of its great network of wires stretching across the continents into every city, town and hamlet.

While the time and expense saved by transcontinental and interurban messages is vast, it is exceeded by that saved in the multitude of telephonic communications carried on in our cities and towns. The telephone has contributed greatly to the mitigation of congestion in our large cities by making it unnecessary for offices, salesrooms and factories to be located within a short distance of each other, since business can be transacted as well if they are located in different parts of the city. The lofty office building owes its existence in part to the telephone, which keeps the occupants of any office in touch with any other office in the building or outside it.

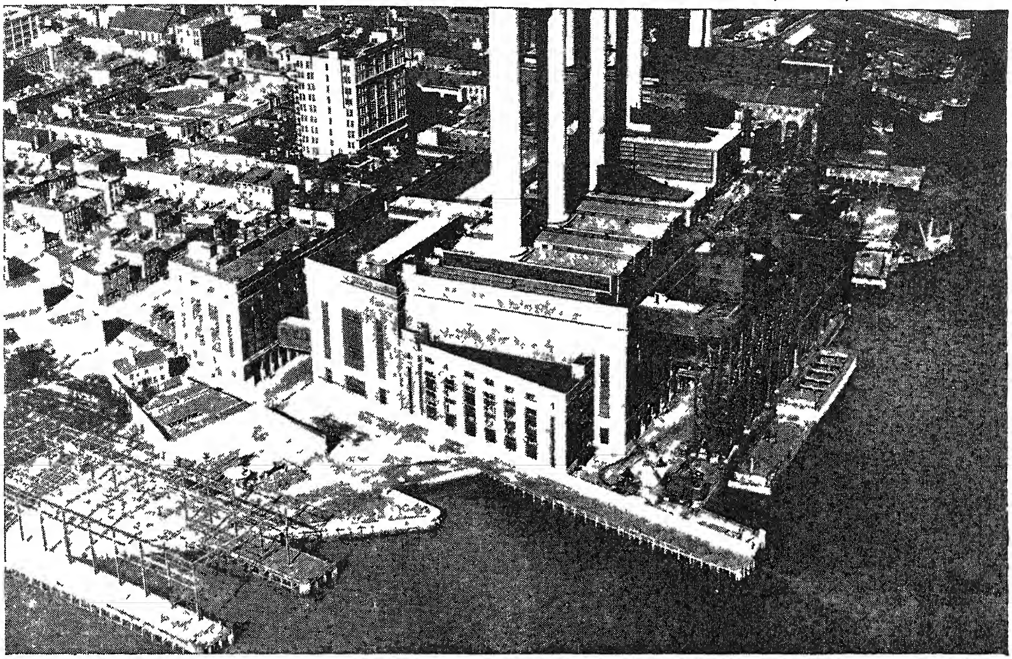
Transmission of intelligence by means of electricity reached its highest development not long ago when a man in Washington spoke simultaneously to a man in Paris and another in Honolulu without using the customary connecting wires. Aladdin himself could not have demanded a greater task of his powerful genie. With the advent of the wireless telephone, passengers on ships at sea may converse as easily with friends on shore as if located in the same building. The transmission of sound or articulated words through the medium of electricity has been extended from the few hundred yards — familiar to our forefathers — to thousands of miles; speech of man which in the nineteenth century bridged only our smallest rivers is now made to carry across the broad ocean or to jump between the continental shores. It only remains for the scientists of the twentieth century to develop the established principle of electric sound propagation to the end that oral communication may be easily established between any two earthly inhabitants however far apart, and without great expense.

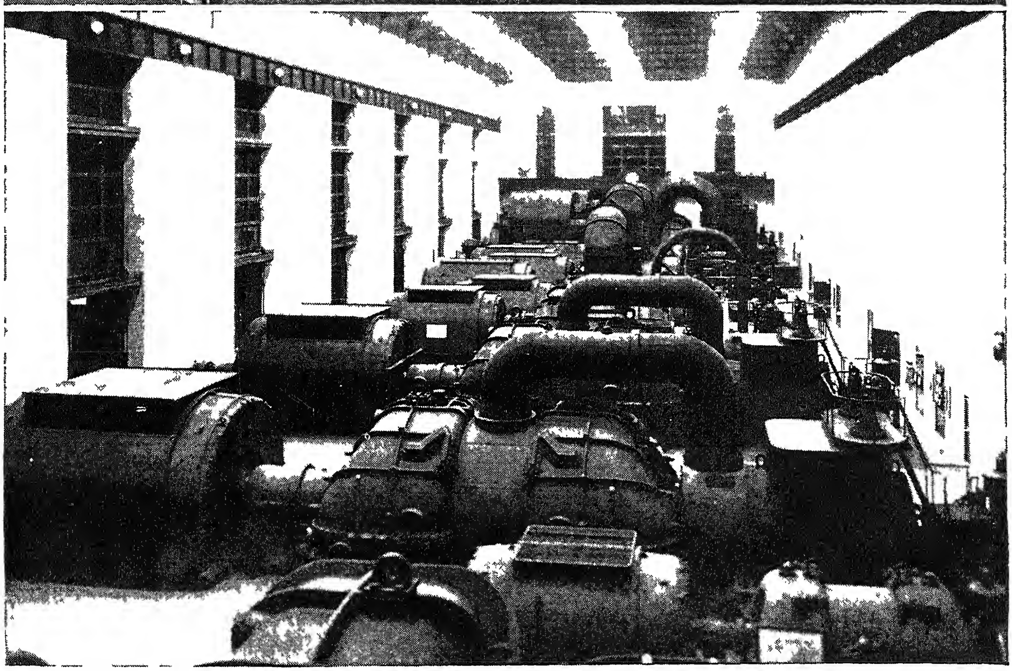
The servitude of electricity to man and its effect upon civilization perhaps is no more strikingly illustrated than in its use as a medium in the transmission of energy. Man from time immemorial has made use of other sources than human energy; the use of animal energy dates back to antiquity, and we have evidence of the early use of the energy of falling water. In every instance, however, the point of application of the energy and its source was by necessity coincident. The water-wheel and the grist-mill of the ancients were located side by side, the waterfall fixing the site of the mill. Comparatively few such sources of energy could be utilized, however, since the greater number of our waterfalls are located in inaccessible mountainous regions to which the transportation of raw materials would prove difficult and expensive.

The development of the steam engine made it increasingly important that some agency be provided for the transmission of energy from the source to the consumer, since the steam engine could be operated most economically in those regions where fuel was abundant or easily transported from the mine. When conditions prompted the use of steam-engine power at tide-water, coal in many instances could be transported in ships at low cost, but inland cities were only supplied at greater expense. The same agency that makes it possible for man to converse at great distances with his fellow-men can now be used to transmit energy from the mountain waterfall or from the coal mine to a distant city. Manufacturing enterprises can thus be carried on in localities where labor and raw materials are most abundant, the required energy being supplied from a source located hundreds of miles away. Favorable locations can be selected for both energy conversion and factory site, the two being connected by a transmission line by means of which electricity delivers energy from one site to the other. In this respect the modern genie does his work somewhat grudgingly, however, for he has yet to be stirred to bridge the distances to which he carries the human voice. The extension of the distance to which energy may be transmitted economically from the present distance of some four hundred miles to greater distances is one of the most pressing problems which confronts the scientists of our century

With reference to the conversion of the chemical energy of coal into electrical energy, the electrical transmission of that energy has in addition made possible the centralization of our power plants, with a consequent decreased cost of the electric energy. The possibility of transmission of energy over great distances has then brought about the construction of enormous power plants containing converting machines of such great size that the resulting cost of energy per unit is rendered low and within the reach of the individual consumer. The extensive use of electricity in the factory and the home is in a large measure due to the consolidation of our power plants, which in turn is made possible by the efficient transmission of electric energy to any point in the surrounding region.

HERE STEAM IN HARNESS PROVIDES 1,000,000 H.P.

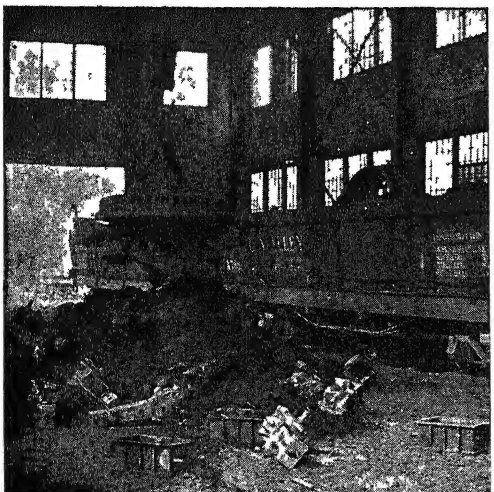




THE HUDSON AVENUE GENERATING STATION OF THE CONSOLIDATED EDISON CO. OF N. Y.

The one million horsepower (770,000 kilowatts) of this steam-electric generating plant are provided by eight turbines of the following capacities: three of 50,000 kilowatts each; one, 80,000 kilowatts; two, 110,000 kilowatts each, and two of 160,000 kilowatts each. Each of the eight turbines is operated from steam from four boilers, a total of thirty-two boilers. The last eight boilers installed serve the two largest generating units and have a capacity of 452,000 pounds of steam an hour. The generating equipment operates at moderate steam pressures in order to minimize the possibility of mechanical failure.

In most modern industrial plants the familiar arrangement of shafting, belts and pulleys has given way before the more flexible electric drive. The large amount of energy formerly wasted in mechanical drive may now be utilized for driving machinery. Buildings may be erected at less cost; they may be grouped or extended without regard to the limitations impressed by shaft drive, and the individual machines may be located in positions such that the manufactured product requires a minimum of handling. The elimination of overhead belting leaves more head room for the operation of cranes and makes for better illumination. Ab-



Courtesy of Electric Controller & Manufacturing Co.
LOADING CAR COUPLINGS, STILL TOO HOT TO HANDLE, WITH AN ELECTRIC LIFTING MAGNET

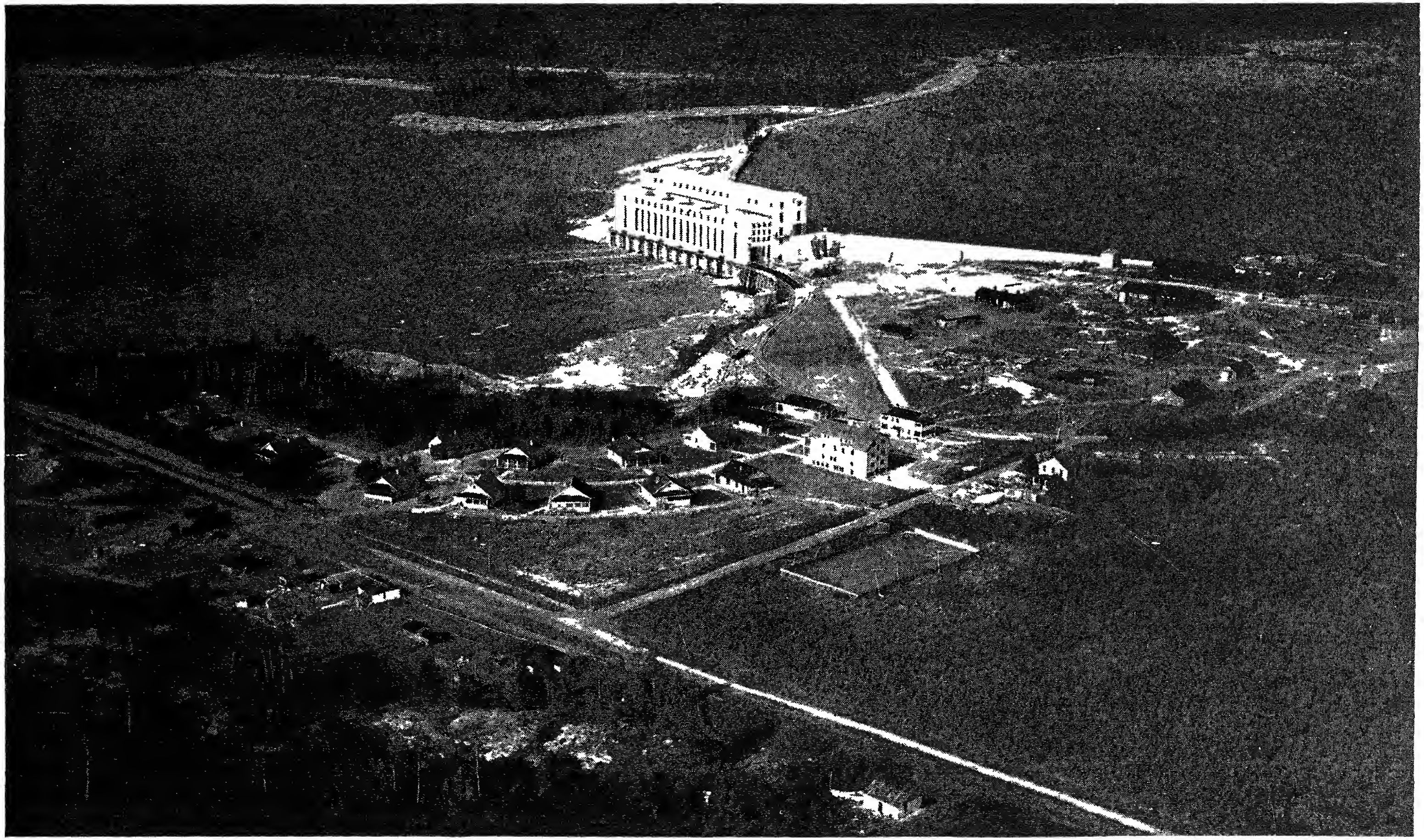
sence of dripping oil from shaft-hangers and of dust agitation by belts brings about greater cleanliness in operation, with increased health to the employees and less damage to the finished product. Electric drive has proved more reliable than the shaft drive, and its flexibility is such that individual machines may be driven for overtime work without bringing the entire plant up to speed. Many operations which require accurate speed control are carried on more effectively. Simplicity of speed adjustment and ample power reserve make for increased production at a decreased manufacturing cost. Accidents have been found less frequent in the electrically driven plant. This fact, together with the decreased noise, better illumination and cleaner surroundings, is of the greatest importance to the employer and employee, since labor finds greater contentment in the working conditions. The factory itself need no longer scatter smoke from its chimneys or dust from its ventilators over the surrounding region since electrical devices are available for reclaiming the unburned cinders and soot particles from chimneys or the valuable cement dust, for example, which might otherwise be lost. The electric ozonizer installed in flues over vats emitting foul odors removes the odors from the rising gases so that plants which must otherwise be located outside of the cities can be established in more convenient places without opposition. In plants where iron of various shapes must be transported, powerful electric lifting magnets inside or outside in rain or snow give increased capacity for handling materials.

The use of electric power in transportation systems

Electricity also provides motive power for our railroad systems. The old-fashioned steam locomotive was inefficient; it belched forth quantities of smoke; it was subject to a high rate of depreciation. Therefore the first electric locomotives were hailed with delight. They derived ample power from a central station; they required less maintenance expense; no smoke nuisance was associated with them. They seemed destined to reign supreme in the field of long-range land transportation. Today, however, though they are still popular, they have not been as widely adopted as had been predicted. Modern steam locomotives, far more efficient than their predecessors, have had a new lease of life; Diesel-electric engines have also come to the fore.

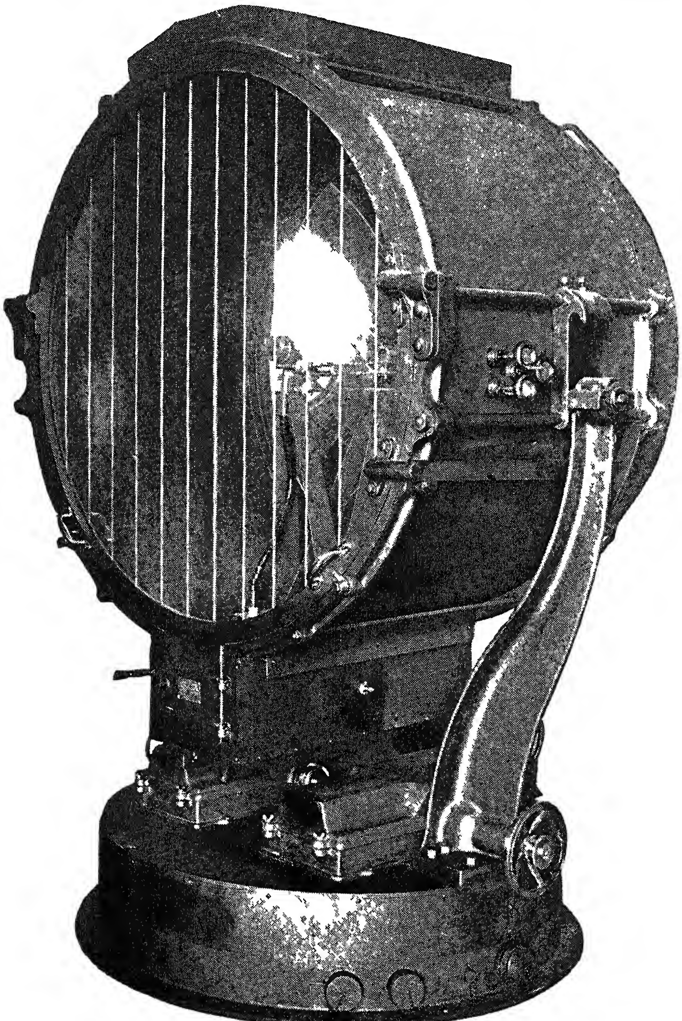
Electric traction is still widely used for local surface and underground lines, although busses, driven by gasoline or Diesel engines, are becoming increasingly popular. Electrically driven subway or street cars do not emit objectionable fumes; furthermore, they can be operated singly or in trains, since each car has its own motor.

A WESTERN CURRENT THAT SETS FREE MANY CURRENTS OF INDUSTRY



GREAT FALLS DEVELOPMENT, WINNIPEG RIVER, MANITOBA
168,000 h.p. Manitoba Power Company Limited.

This use of electricity has been of incalculable benefit to modern housing conditions, since many city workers are able to reside in the more healthful outskirts of the cities without consuming great time in transit from the home to the shop or office Those who live in the densely populated city districts, on the other hand, are provided with inexpensive transportation to the open country where recreation or rest from city turmoil is assured Social intercourse, business transactions, sightseeing — all would suffer without the smokeless, noiseless electric motor. Interurban rapid transit systems developed in the less densely populated regions furnish passenger and small freight service to the bordering farms. Means are thus provided for the convenient exchange of country produce for city merchandise. The transportation of passengers and commodities by electric traction, the electric telephone and telegraph shorten distances to the extent that the inhabitants of cities and towns alike are in close communication and may share the advantages of each.

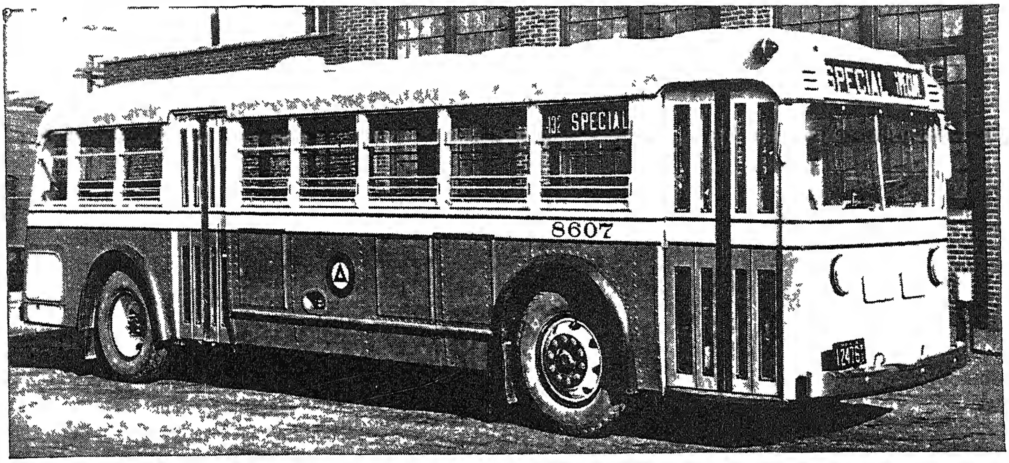


Courtesy General Electric Co

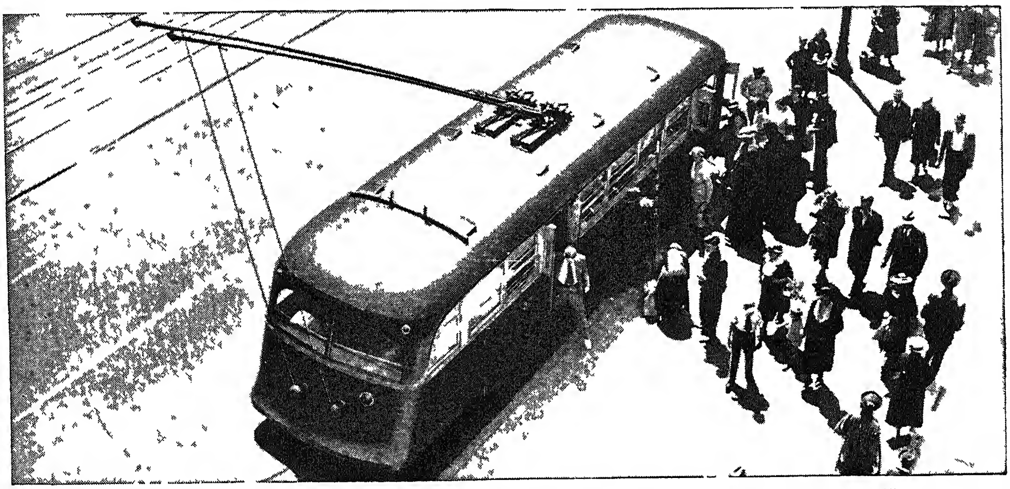
A 60-INCH ELECTRIC SEARCHLIGHT THAT WILL ILLUMINATE OBJECTS TEN MILES AWAY

One need only look down at night from a hilltop upon a large city spread out on the plain below to appreciate the effect of the electric lamp upon modern life Gleaming lights are seen on every hand illuminating streets, office buildings, stores and homes. Moving lights on street cars and automobiles circulate back and forth and myriads of electric signs, bejeweled with changing colors, burst into view with ceaseless activity. All this has taken place since the time when Abraham Lincoln lay on the floor before a flaring fireplace working his sums Electricity has made the present generation independent of the sun, business is no longer dependent on the length of the day, and the hidden terrors in the blackness of night are scattered beyond the pale of light. Great searchlights containing a light source rivaling that of the sun may project their bright beams over miles of land and sea Command the modern genie to illuminate your book, light your highway, penetrate the walls of your houses even, and he will obey you. Push the electric switch and darkness is changed to light.

MODERN ELECTRICAL TRANSPORTATION



THIS DIESEL-ELECTRIC BUS GENERATES ITS OWN POWER



A TRACKLESS TROLLEY COACH WHICH DERIVES ITS POWER FROM OVERHEAD LINES

Photos courtesy General Electric Co.

A MODERN VERSION OF THE TROLLEY CAR

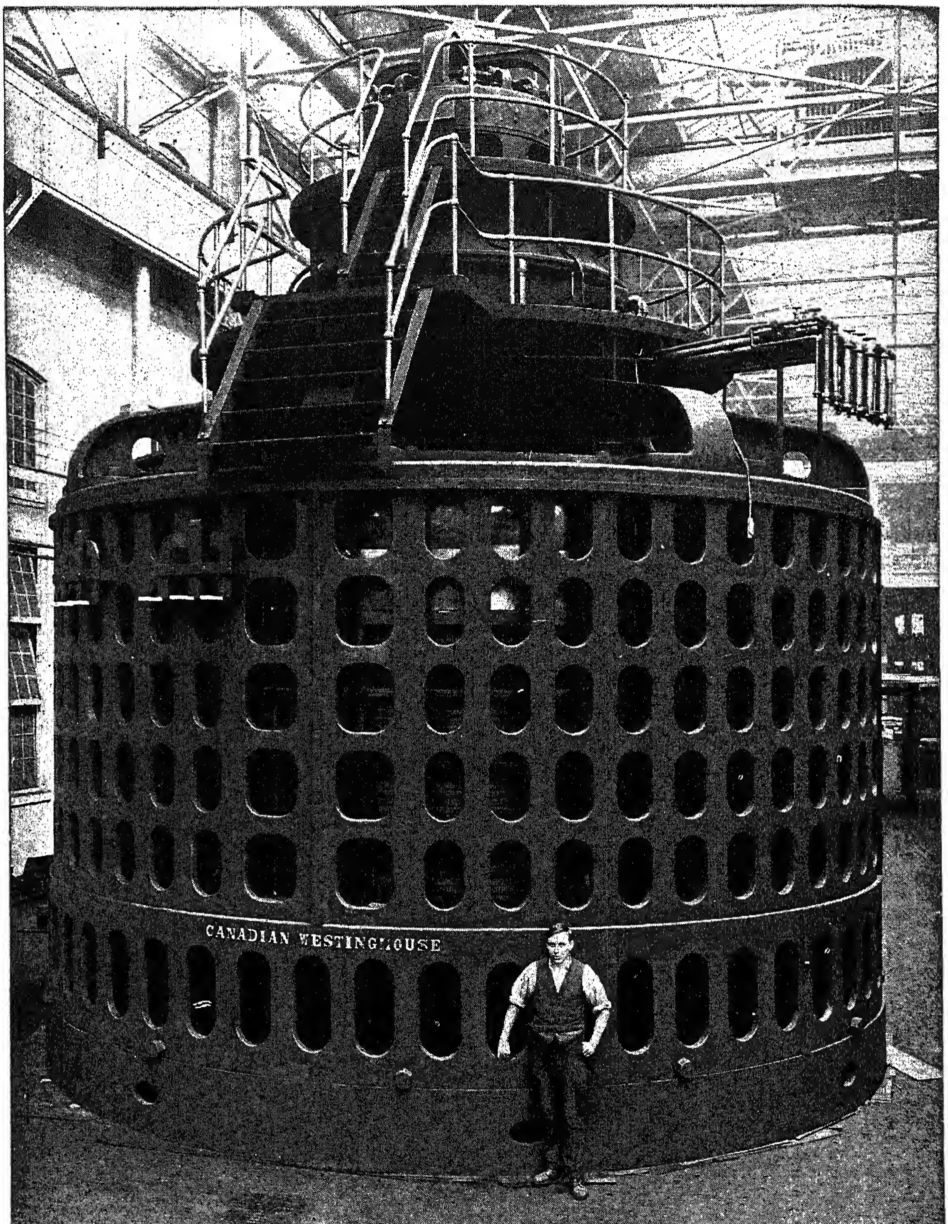


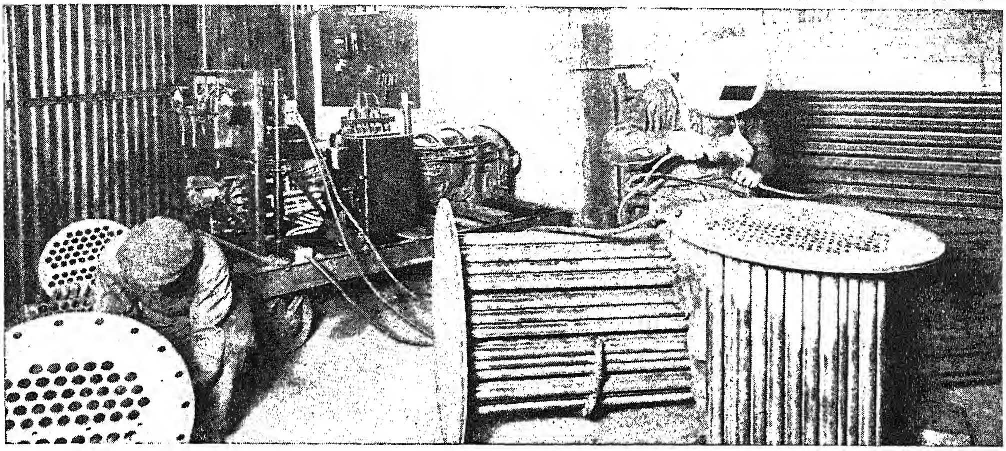
Photo Ewing Galloway, N. Y.

BALANCE AND POWER EXHIBITED BY A LARGE TURBINE ELECTRIC GENERATOR

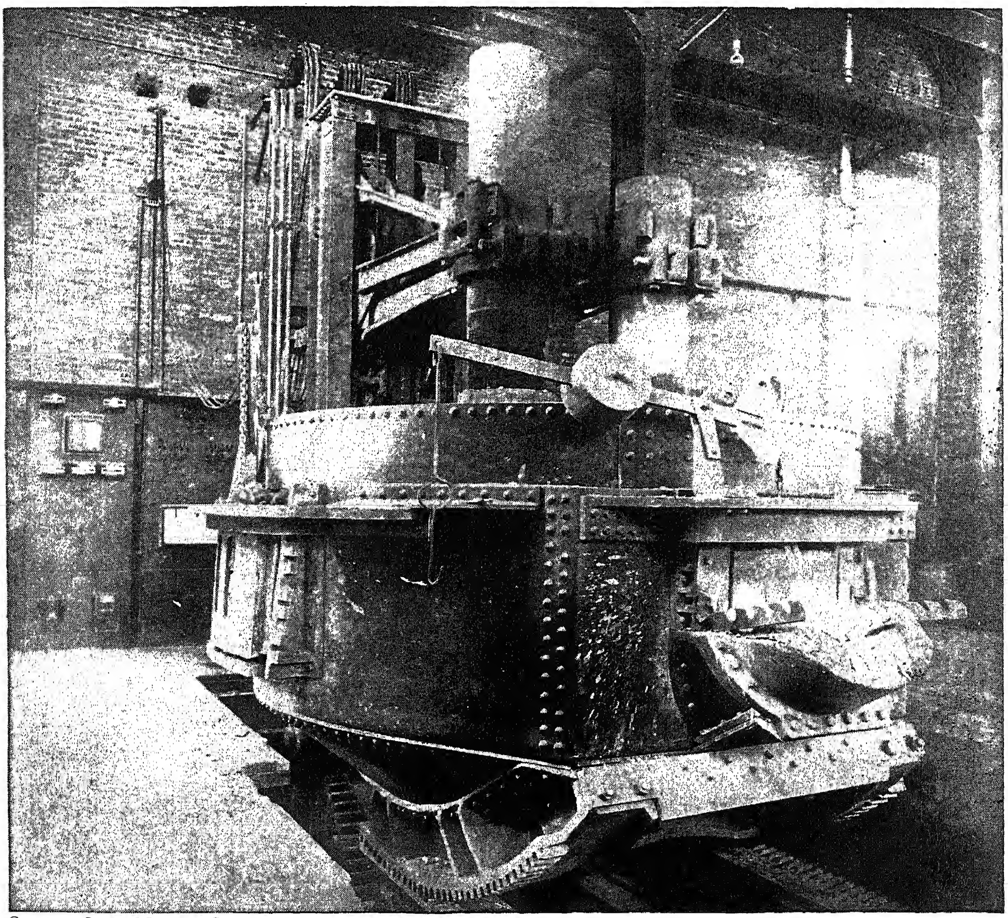
One of the 55,000 horse-power generators in the Queenston-Chippawa hydro-electric power plant. Turbines of this kind are supported on a cushion of water with such delicate accuracy that, unless braked, it takes twelve hours after the power is shut off for them to come to complete rest.

In addition to the service which electricity renders mankind in driving the machinery of our industrial plants, it may be made to extract the valuable constituents of our mineral deposits for utilization in the arts. The electric current may thus separate pure metal from other materials with which it is naturally associated, a task which in most cases could not be accomplished as efficiently or as cheaply by any other agency. These metals may then be plated in layers of any desired

UTILIZING THE HEAT OF THE ELECTRIC ARC



ELECTRIC ARC WELDING STEEL TUBES INTO TUBE SHEETS WITH A PORTABLE WELDING SET

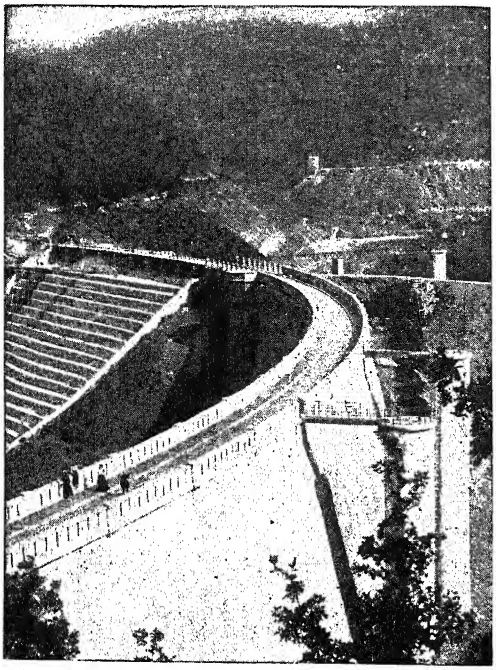


Courtesy General Electric Co.

SIX-TON HEROULT ELECTRIC FURNACE

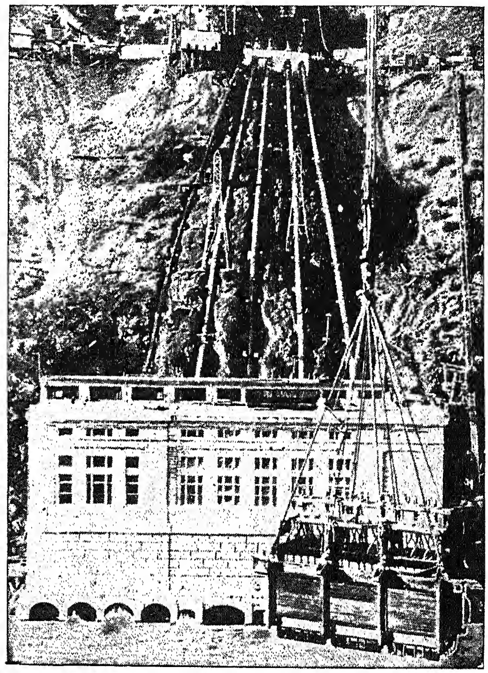
An electric arc playing between the two vertical carbons produces a temperature under which all solid materials become liquid.

thickness on cheaper materials by the same electric current. This plating property of electricity is utilized for producing the multitude of iron utensils protected against corrosion by a coating of tin or zinc. The tin can in which the fruits and vegetables of the summer season are preserved for winter consumption owes its existence to the electric current. Many materials which can only be manufactured or extracted from the adulterated sources at high temperatures would be unavailable without the electric furnace. In the high temperature of the electric arc, materials which are found infrequently in nature may be produced in large quantities for the use of mankind. Graphite, carbide and many other substances, even diamonds and rubies, may be artificially manufactured by the electric servant. Many kinds of electric welding machines are in use which swiftly attach one metal to another; wire fencing, for example, being woven as in a loom and each point of contact welded strongly together.



THE DAM IN THE EIFEL VALLEY BEFORE FLOODING
Note the step spillway, reinforcing the dam's resistance to the coming thrust of backed-up water.

Swift as electricity appears in the forked lightning and in the ocean cable it may still be stored in batteries, which after being charged may be made to deliver power when needed in the automobile, the submarine or the airplane, for example. No longer does the miner grope his way through the black caverns aided by a flickering candle or lamp. A small storage battery slung across his back delivers energy to a powerful electric lamp which projects a brilliant beam of light from his cap to the path before him.



A POWER-GENERATING PLANT IN CALIFORNIA
Conveying across the Feather River a 10,000-kilowatt, 100,000-volt transformer to a hydro-electric station.

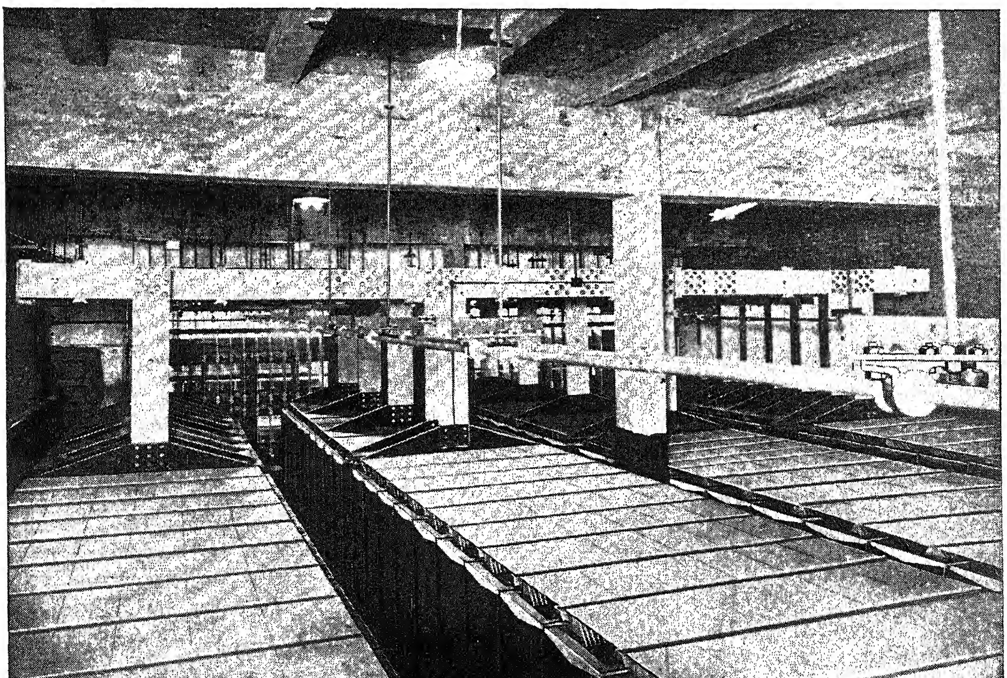
Electric power stations in the event of breakdown may continue to supply energy which has been stored in a huge battery. Electricity may be produced in small amounts by another kind of battery by chemical reaction without charging. Such primary batteries in a variety of sizes find extensive use in portable flashlights, for driving toy motors, for bell ringing and for house telephones.

While heavy electric currents passed through the human body produce fatal muscular reaction and are used in many

Courtesy Edison Storage Battery Co.

MINER EQUIPPED WITH EDISON NICKEL IRON ALKALINE STORAGE BATTERY AND ELECTRIC HEADLIGHT

Note the wide arc of illumination.

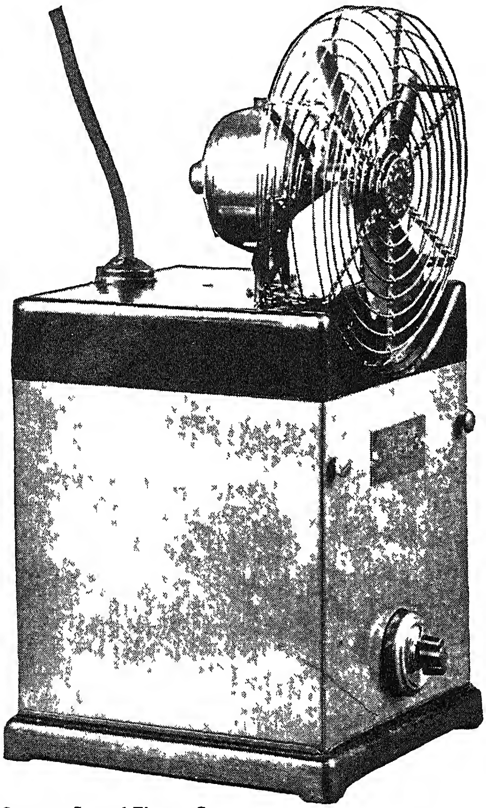


Courtesy Electric Storage Battery Co.

A LARGE CENTRAL STATION STORAGE BATTERY

Which stands ready to supply electricity for light and power should other sources fail.

states for the electrocution of criminals, weaker currents have been found to possess curative properties in connection with certain nervous diseases. In addition to the direct application of electric current to his patients, the modern physician makes extensive use of electricity in X-ray tubes for photographing internal deformities and fractures and in powerful electro-magnets which will extract particles of iron from the eyeball, or other parts of the body. Air passed through plates

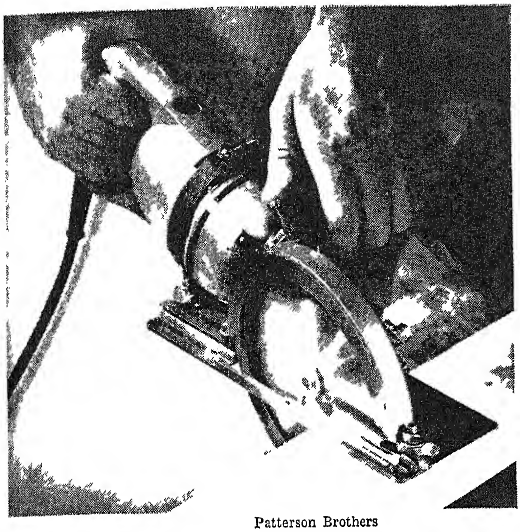


Courtesy General Electric Co
ELECTRIC FAN THAT CIRCULATES AIR CHARGED WITH OZONE

highly charged with electricity is charged with ozone which acts as a powerful deodorizer for the sick-room and as a stimulant to those who breathe it. Plant life subjected to a mild electrical discharge grows more vigorously and such electrical forcing, while not adapted to large areas, is used successfully in hothouses for hastening the growth and for increasing the quantity of flowers and vegetables.

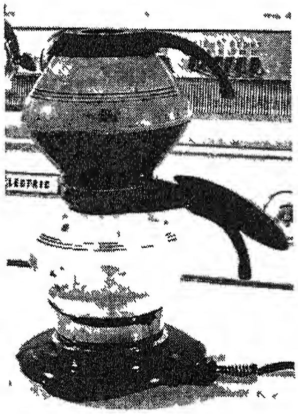
Many church organs are played electrically from a console, which is connected to the organ by a cable of wires with the advantage that the console is movable and may be located at will in any part of the building. Electrical musical instruments are being developed in which the vibrations of the electric current are converted into sound with unsurpassed possibilities for variation of quality as well as pitch Sound of almost any musical instrument may be simulated accurately by a single instrument, or the sound of several musical instruments may be reproduced simultaneously, giving the effect of an orchestra. Electric refrigeration has completely revolutionized the dairy and the fruit and vegetable shipping industries It has also contributed in no small measure to lighten the daily work of the housewife in the home.

It will be seen that man has harnessed electricity to do for him practically everything that he commands Man has even made electricity bring him moving pictures of distant scenes in several ways—through space by means of television and through wires by means of coaxial cables. Present research along these lines may reveal the possibility of adding to the telephone instrument a device whereby those conversing will be able to see, as well as hear each other. The accomplishment of the transmission of sight, as well as of hearing, will weld the last link in the chain of long-distance communication. Electricity will then have transported the person with whom you wish to converse to your very side. An electrical device is available by means of which the business man may sit at his desk and write on a piece of paper some miles distant. He may, for example, make his signature on a check in another office without traveling the intervening distance. If he calls up an acquaintance on the telephone and is informed of his absence, he may still speak his message through the telephone into an electrical device on the distant desk, and when the acquaintance returns he can then listen to the message word for word just as it was spoken.



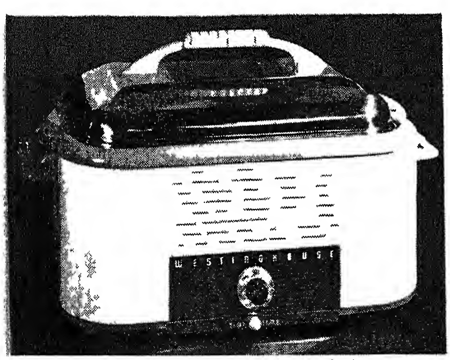
Patterson Brothers

Handyman's aid—a portable saw.



General Electric

An automatic coffee-maker.

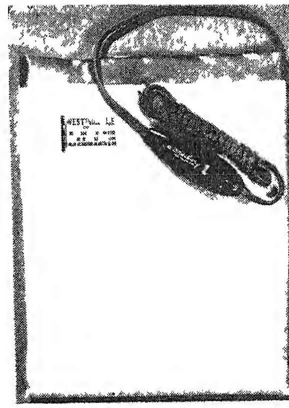


Westinghouse

An all-purpose roaster-oven.

Three-heat model warming pad

Westinghouse



Light, large-base steam and dry iron.

Westinghouse

ELECTRICAL HOME APPLIANCES

Pictured here are various convenient electrical devices that have made modern home living much simpler and more comfortable The magic of electricity has revolutionized our mode of living tasks that were once time-consuming and toilsome are now accomplished speedily and with a minimum of effort.

A convenient electric pop-up toaster.

General Electric

Consideration of the multitude of uses to which electricity may be applied would seem to indicate that the electric current possesses an unlimited number of properties. The contrary is true, however, since all the detailed applications which we have noted are dependent in their execution upon a very few properties. An electric current, for example, causes any substance through which it flows to become heated. All heat or light applications depend upon this principle. Furthermore, any substance carrying current and located in a magnetic field is acted upon by a force which tends to push the conductor through the magnetic field. All electric motors operate on this principle; the same is true of any electrical device in which motion is produced. The third property, the chemical effect, is produced when an electric current is made to flow through certain chemical substances. The result is a changed structure of the substance, certain elements or compounds being liberated from the aggregate mass. There are then only three basic properties of electric current which manifest themselves so frequently in modern civilization. We have only to add the secondary effect of electric current on living organisms and its functions are made complete. The production of electric current is accomplished usually by one of two methods. In either case the current is made to flow by a pressure or force called an electromotive force. An electric pressure or electromotive force is produced in any wire when a magnetic flux surrounding the wire is made to change constantly in a strength. This is the fundamental principle of operation of all dynamo-electric machines. The other method involves only the contact of two dissimilar substances and is the underlying principle of electric batteries.

The varied and important uses which man has made of electricity are thus seen to be based upon a less complicated substance than is generally imagined. Turn on an electric lamp and the tungsten filament is heated to a light-emitting incandescence by the heat property. It is the same property that toasts our bread in the electric toaster, boils our eggs or roasts our meat in the electric oven. In the gasoline engine the gas is exploded by the hot spark produced electrically at the tips of the spark plug, and in the electric furnace some of the highest temperatures produced artificially are created within a huge electric arc. Conversion of electric power to mechanical power is produced always by the reaction between electric current and magnetic flux. The same property that vibrates the hammer of our electric door-bells speeds the massive electric locomotive. The chemical effect is the same whether it be utilized for reclaiming metallic aluminum from its compounds or for galvanizing a coat of zinc on sheet iron. It is the very simplicity of electricity which has made it seem complicated, because its applications have been so clearly conceived and perfected that machines and devices containing thousands of parts have been constructed. If electricity had been more complicated in its properties man could not have applied it successfully to so many important uses.

LABOR AND WEALTH

Increasing the Supply of Commodities

WE now come to the interesting problems that have to do with the utilization of labor. In the first place, we shall do well to state our assumption that the primary object of trade and industry is not to make but to save work. The conception that the making of work, or the giving of employment, is an end in itself is one of the oldest of all economic fallacies. We must remember, however, that if this conception is still cherished it is because the saving of labor in an imperfect civilization is accompanied by loss and suffering to individuals through consequent unemployment. We must not, therefore, be tempted to regard it lightly nor to dismiss with disfavor the worker or employer whose circumstances cause him to entertain the delusion that the giving of employment is an end in itself.

The fallacy we refer to is often uttered by those who excuse the most luxurious and wasteful expenditure on the grounds that it creates work. Where there is wanton extravagance in spending, there are never lacking those who are always ready to make excuses for it on the assumption that it gives employment. If the making of work is the ultimate goal for which we aim in life, then it would seem obvious that, the more laborious trade and industry can be made, the better they are for mankind. Why plow, when it would obviously create more work to loosen the soil of a field by digging with a stick or even by breaking up the lumps of dirt with the fingers? Why use a truck, not to mention a train, when more work would be made by dragging loads over a road by manual labor? Why, indeed, make a road, when it is obvious that, if it did not exist, there would be much more work made in moving things about?

When a worker says that he is suffering from lack of employment, what he really means, from an economic standpoint, is that he is suffering from lack of income, and work presents itself to him as a means of obtaining that income. We must not wonder, therefore, if the necessity of finding work exists for him as the main object of life, and we should not criticize him if he is only too prone to believe in the economic fallacy to which we have referred. Indeed, it is not much help to the unemployed worker to be reminded that one of the principal objects of civilization is to minimize the amount of toil that is necessary for producing a given amount of comfort or a given quantity of utilities.

With the advent of trade and industrial unions the individual worker has, to a degree, become a significant part of an economic chain, which he helps to create and helps to control; but he is still forced to consider the immediate point — that is, how to get a wage. An intelligent worker will realize that what most needs to be accomplished in his immediate neighborhood is, for example, to construct new and better houses for himself and others like him in order to enable them to lead decent and useful lives. He may know this economic truth, but of what avail is the knowledge to him? He must find income by obtaining employment. If, therefore, the work offered him is to assist in the building up of a luxury, and, in effect, to waste his working energies from a social point of view, he must still accept the offer of employment. Consequently, he will regard the making of work — however foolish, wasteful and absurd — as the immediately desirable thing, since he must provide the necessities of life for his family.

The fallacy of thinking that work is what mankind wants

In spite of the castigation of economists, the fallacy of making work, therefore, remains current, and is only too likely to do so for a long time. Senior, who wrote in the first half of the nineteenth century, very effectively dealt with the subject when he said: "Those who maintain that unproductive consumption does good by affording employment must forget that it is not employment, but food, clothing, shelter and fuel — in short, the materials of subsistence and comfort — that the laboring classes require. The word 'employment' is merely a concise form of designating toil, trouble, exposure and fatigue. It is indeed sometimes elliptically used as implying the subsistence which is purchased by enduring it. A poor man complains that he wants work. He might work to his heart's content, and with no man's leave, if he chose to carry stones from the bottom to the top of a hill. But what he wants is work as a means of obtaining payment. He would be happy to get the payment without the work.

"Toil, exposure and fatigue, *per se*, are evils, and the less of them that is required for obtaining a given amount of subsistence and comfort, or, in other words, the greater the facility of obtaining that given amount, the better, other things being equal, will be the condition of the laboring classes; indeed, of all classes in the community."

Ruskin, writing as long ago as 1879, exposing the fallacy of "making work", as uttered by the then Bishop of Manchester, said: "I cannot easily express the astonishment with which I find a man of your lordship's intelligence taking up the common phrase of 'giving employment', as if, indeed, labor were the best gift which the rich could bestow on the poor. Of course, every idle vagabond, be he rich or poor, 'gives employment' to some otherwise enough burdened wretch to provide his dinner and clothes for him; and every vicious vagabond, in the destructive power of his vice, gives sorrowful occupation to the energies of resisting and renovating virtue. The idle child who litters its nursery and tears its frock gives employment to the housemaid and seamstress; the idle woman who litters her drawing-room with trinkets, and is ashamed to be seen twice in the same dress, is, in your lordship's view, the enlightened supporter of the arts and manufactures of her country."

The saving of labor the real road to the increase of wealth

The royal road to wealth is by the saving of labor. The people of the world become grouped and even crowded in those parts of the world in which a definite amount of work can be done with the least amount of labor. That is why, before the days of power-development, fertility was the chief magnet for population, and that is why, again, at a later date, as we saw in former chapters, the discovery of the use of coal drew men to places where cheap fuel helped them to work most easily.

The division of labor has largely and increasingly helped man to economize effort. The distribution of men, of tribes, and even of nations, amongst different occupations naturally arose from the discovery of this great economic truth. We even find the division of labor among the higher orders of insects, and among men it has existed, in some form, in all recorded history. By following a particular line of effort, one man became an expert carpenter, while another became an expert blacksmith, and each was able to do better work because he stuck to his particular calling. Thus men learned to work for each other, and, by doing so, to save work, and to get more from their efforts than if they each attempted to follow all trades, and each attempted to do everything for himself. Trade, of course, thus had its origin, the division of labor making it necessary to exchange the products of one calling for the products of others.

The grouping of industries in districts as a means of economizing labor

Both in ancient and in modern times the division of labor has found expression in the devotion of entire districts to a particular form of industry, the products of which are sent out of the district in exchange for the subsistence of the district.

The United States affords many excellent examples of the localization of industries, which is really another name for the geographical division of labor. Thus the boot and shoe industry is predominant in Massachusetts; collars and cuffs are made in Troy, New York; gloves are produced in Gloversville and Johnstown, New York; brassware in Waterbury, Connecticut; carpets, in Philadelphia; jewelry, in Providence, Rhode Island, and the neighboring towns of Attleboro and North Attleboro, Massachusetts; plated silverware is made in Meriden, Connecticut; silk, in Paterson, New Jersey. Other examples might be given, and, of course, the generally recognized division of the country into industrial and agricultural sections, characterized by different types of industries, and by the dominance of different crops is itself an example of the territorial division of labor.

Different causes that explain the localization of industries

Different causes explain the localization of different industries. The proximity of raw material or of fuel may be the determining factor. Or it may be the accessibility of markets or the presence of water-power. The availability of a trained labor supply counts for much, and so does what has been called the "momentum of an early start". These last two causes explain the persistence of a particular industry in a certain locality generation after generation. Frequently, however, no one of these factors, and no combination of these factors, seems adequate to explain the presence or the development of a certain industry in a certain place. Here we have to fall back upon the human factor, — the variable in so many economic laws. Physical and economic facts will sometimes suffice to explain just why some industries should be distributed as they are, but, in other instances, the only possible explanation is that men of energy have set themselves at work to build up a great industry in a particular locality, and have succeeded.

The principle of the division of labor is thus very widely practised; and what it amounts to is that a certain amount of labor is saved by the division.

Adam Smith used a very effective illustration of the economy effected by the division of labor. He pointed out that if a blacksmith had to make nails without being used to the job, he would only make 200 or 300 nails a day, and not very good ones into the bargain. With practice, he might learn to make 800 or 1000 nails in a day. But bring up a boy to the nail-making trade, and he could turn out 2300 nails of the same kind in the same time. If Adam Smith lived now, he could take his illustration further and point out that, with the aid of suitable machinery, a man, or indeed a boy, can now make tens of thousands of nails in eight hours, by devoting himself exclusively during the day to the same machine. And it is not only dexterity that is gained by a man who devotes himself to one calling only. A great deal of time is saved, because the pursuit of a particular task saves the time which is lost in changing from one job to another.

The effects of the coming of machinery in subdividing callings

Preparing to do work necessarily takes time — the assembling of tools, materials, etc. — and if, therefore, a man did many kinds of work during a day, he would have to waste a lot of his day in preparing for each particular job and clearing up after it.

With the coming of machinery, the division of labor took a new form, and one very far-reaching in its effects. It served to *subdivide callings*, and in many cases to destroy old and honorable employments. The devotion of a man's life to the trade of shoemaking is an example of the division of labor. The breaking up of shoemaking into minute subdivisions, each of which is followed by a particular set of men or women, destroys shoemaking in the old sense altogether, and substitutes a highly complicated, organized industry, *the workers in which do not know how to make shoes at all.* It is a strange thought that there are thousands of men and women making shoes in the United States today who would be at a loss to know what to do if they had to make a pair of shoes from start to finish. They only know their infinitesimal bit which contributes to make the completed whole.

The apparently high cost of machines that make cheap things

Sometimes the size or weight of a machine or press devoted to the production of some very small part of a commodity by the modern system of machine production seems almost ludicrous. A press costing many thousands of dollars may be solely devoted to stamping out bits of metal. The capital so devoted saves an enormous amount of labor, and enables cheap production to be attained. The costly machine at each stroke saves a quite considerable amount of work. Other costly machines do the same service for other small parts of the ultimate commodity. The final outcome is that a complicated article, such as a shoe, is produced as the addition of a large number of very small fractions of labor, with consequent great cheapness.

No better illustration of the process can be given than its application to the making of watches and clocks. When, in the early days of the watchmaker's art, a workman of great skill and ingenuity produced an entire watch, the result was a very costly and sometimes a very beautiful and ingenious article, which cost so much in labor that it could only be enjoyed by a few. A king, a nobleman or a rich merchant might possess such an object with some difficulty, for the wonder of the world at large. Later, when there was some amount of division of labor introduced, as in the justly celebrated Swiss watch industry, a watch came into existence which could be afforded even by the middle class. Nowadays watches can be produced at so low a cost that they can be sold for a dollar or two and can be owned by any one. These quite efficient articles are produced by stamping out the various parts by separate machines, and putting those easily made parts together. The result is a standard article, each of the parts of which is interchangeable with each of the smaller parts of any other of the hundreds of thousands of watches of the same kind produced.

In the last few years the same principle has been applied in America to the making of what was only lately a great luxury, the automobile.

The cheapening of the automobile by standardization and use of machines

If you apply division of labor as understood by Adam Smith to the making of an automobile, you get a very costly article indeed. We have applied to the automobile the same principle of standardization which is found in the shoe industry; and hundreds of thousands of cars of the same pattern are turned out, each of the separate parts of which has been produced under the system of extreme division of labor. As a consequence, we find excellent cars offered at what seems an extraordinarily low price, but which is not extraordinary in view of the economical method of production.

The standardization of products has introduced great economies, not only in the machine industries, but in other fields as well. The whole tendency of the routine, mechanical methods of the modern factory system is to turn out products of definite kinds and of definite grades. Great economies are thus effected at the loss sometimes of the opportunity for personal expression on the part of the workman, and for the full and accurate satisfaction of the personal tastes of the consumer. The machine process is standardizing consumption as well as production. Economy and abundance are purchased at the expense of individuality and variety. To anyone who has viewed the problem without prejudice the conclusion must be that there has been a large net gain. Never before in the world's history have so many people been supported at so high a general level of comfort as in those modern countries which have best mastered and utilized the principles of the division of labor and of the factory system.

Throughout the practice of the division of labor it is apparent that there runs the principle of increasing wealth by saving labor; and this is as true of the old and simpler form of the process, which saw craftsmen engaged in carrying out in its entirety the manufacture of an article, as it is of the later form, in which one kind of manufacture is split up into many tiny individual operations.

The recentness of the machine age, and its great influence on human society

The inventor thus presents himself as a saver of labor, and since the beginning of the second half of the eighteenth century he has worked marvels in this direction. The machines were first supplied with great advantage to the textile industries. It was in 1764 that Hargreaves introduced the spinning-jenny. By and by there came the power-loom, and more than a hundred years have now elapsed since the hand-weavers' trade passed away. In 1769, Watt took out his steam-engine patent, and by 1781 he had made steam-working effective. As we have already seen, the steam-engine was really called into existence by the necessity to pump coal mines. In 1807, steam was first used in navigation, and it was in 1825 that the Stockton-Darlington railway was opened. In 1838, Brunel's "Great Western" crossed the Atlantic; and in 1831 Faraday discovered magneto-electric induction, the first discovery of the electric current or of galvanism having been made by Galvano on the threshold of the nineteenth century. We name these dates to remind the reader how short a period separates us from the realization by man of the powers which he now commands. It is a span of time which counts for nothing in known history, but yet it is a period long enough to count for the passing of five or six generations, and to produce in the character both of individuals and of society a very considerable effect.

The complexity of the machinery of life under modern divisions of labor

Closely allied in nature to the introduction of machinery into a business is the organization of industries as a whole. Just as we save labor by applying machinery to enable one man to do as much work as many men could do without the machine, so we save labor by uniting the small, scattered units of a business, bringing them under one control, and eliminating all duplications of effort. This process has gone far in connection with not a few industries, and in many instances has become subject to government regulation.

As we have already noted, trade took its origin in the division of labor. As soon as men ceased to do everything for themselves, and divided up occupations between different families or groups, it became necessary to make exchanges in order to secure a varied subsistence. We see a modern community so divided and subdivided that it is true to say that not only does one half not know how the other half lives, but that few indeed of the individuals concerned pause to consider the working of the community as a whole, or the relation of their own share of work to the aggregate of the community's work. The average man does not stop to consider the extraordinary complexity of the organization which feeds him and clothes him and supplies him with comforts in exchange for some contribution, large or small, made towards the general fund of wealth.

Workman and manufacturer alike have little grasp on scheme of things entire

It is true not only of the average workman, but even of the great manufacturer or merchant, that, however intimate he may be with the particular groove in which he himself carries on his operations, he has little grasp of the scheme of things entire. In the old days it was easier to grasp the machinery of life. Foreign trade was very small in dimensions; and for the individual it was easy enough to understand the exchanges that took place in the small market town surrounded by an agricultural belt. The farmers took their produce to market, and found in the city the simple arts which mainly made up the economic balance. Today the population is congregated chiefly in large cities; and in these the complexity of economic forces hides the real nature and effect of transactions, and leaves the "man in the street" largely ignorant of the world. The stores in the towns sell articles which more often than not are made in places remote, and the modern merchant does not always know the real nature of the articles which he sells.

The area of the division of labor has, of course, widened with invention. The railway and the steamship have done more for trade than any other third cause, and at

each stage of their expansion they have widened the area of exchange. In the old days the butcher's shop was a place in which was retailed the meat of animals raised in the vicinity. Transportation next made it possible for people to eat meat grown at a considerable distance, and, combined with cold storage, has now actually made it possible for the Old World to eat the flesh of animals raised in the New World. No more striking instance than this could be given of the fruits of the division of labor.

It has been pointed out by Professor J. R. Commons that in the modern packing house the steer has been "surveyed and laid off like a map". The workers have been classified in over thirty specialized gangs, each man doing but one thing in the division of the carcass and hide. "Skill has become specialized to fit the anatomy" and the varied products sent to the ends of the earth.

International division of labor, and the exchanges to which it leads

This brings us to the *international division of labor*, which is only another branch of that geographical division of labor at which we have already glanced. Within our own country we find one district doing one kind of work, and another district devoted to an entirely different occupation. It is not surprising, therefore, that as between one country and another we find a considerable variation of products. This partly arises from variation of natural gifts. A country rich in power is naturally a manufacturing country. A country rich in fertility is naturally an agricultural country.

Just as a nation gains by the different parts of it being devoted to different occupations, exchanging with each other the products of their labor, so a country gains when its people, producing with facility and abundance certain commodities for which it is particularly suited, exchange those commodities for the products of other lands which have different advantages. It is indeed likely that the modern world would not be able to sustain its present great population had these exchanges not taken place.

International division of labor based on differences in natural resources

It is important to observe that international exchanges rest upon three very different bases, and that two of these are permanent and the other not necessarily so. The first permanent basis is the wide differences which exist in the natural resources of different parts of the world. England has plenty of coal and no sulphur, Italy has plenty of sulphur and no coal.

These are unalterable facts, and as long as coal is useful, Italy will have to get coal, if she needs it, by exporting something which she possesses — say, sulphur or olive oil — in exchange for it. Similarly, England possesses no sulphur, and must get what she needs of it by exchanges with Italy or some other country which produces it. Again the fact is unalterable. A very large part of the trade of the world rests upon such unalterable facts. The climate does not allow England to produce mahogany, or teak, or rubber, or gutta percha, or ivory, or mangoes, or cotton, or hemp, or jute, or cocoa, or coffee, or tea, or oranges, or lemons, or wines, or a host of other things that might be named. With regard to these, she will always have to rely upon supplies won by commerce; and so also it is with the many minerals and metals which her soil either does not produce at all or produces insufficiently for her needs.

It is conceivable that the United States, with its greater area, its larger variety of climates and soils and natural resources, might be able, with relatively less disadvantage, to produce all that it consumed. But in such case it would have to get along without many tropical products (or produce them for itself at extravagant cost) and it would find itself handicapped by the absence of certain important minerals and certain fertilizers. Most of all, it would find that it was producing for itself, with wastefully high expenditure of capital and labor, many commodities which it could have got more easily and more cheaply by exchanging its own best products — the goods it can produce to best advantage — for goods made by other nations. It is especially important to emphasize the fact

that, even if *absolutely* the United States had an advantage over every other country in the world in the production of every conceivable commodity, it would, nevertheless, be profitable for it to let other countries produce those commodities in which the advantages of the United States were *comparatively* least. By devoting itself to the production of the commodities in which its comparative advantages were greatest, the United States would be able through international exchange to get the maximum total wealth product, the maximum national income with a minimum expenditure of capital and labor, and with the smallest drain upon its natural resources. *Comparative advantage*, not absolute advantage, governs international trade.

The second permanent basis of international trade is found in differences of race genius as between the peoples of different countries. We find the people, or part of the people, of a particular country possessing some gift which enables them to excel in a particular branch of work, or to add to it something which gives it individual character and value. Here, again, we are confronted with what may be termed an unalterable basis for trade.

The third basis of trade is acquired skill; and here we have something which, as time has already shown, is a very uncertain basis for the exchange of commodities. Sometimes, by obtaining a start in a particular industry, as England did through the inventions of Hargreaves, Crompton, Arkwright and others, the people of a country seem to acquire a particular talent for handling it. For reasons which are sometimes obvious, sometimes obscure, special skill in particular industries is acquired by the people of certain countries; and when once an industry has obtained a special organization and concentration in a country, it acquires strength by virtue of the fact, coming to possess facilities for obtaining material, labor, etc., which enable its members to work with advantage. There is no absolute permanency in such organizations, however; and it does not follow that, because a certain city or country possesses at this time a strong trade position, it will forever continue to hold it.

It is clear that so far as trade rests upon the third basis we have named — that of acquired skill — there is no permanent basis for trade; and city A in country B, which at present does a fine export trade in a particular article with, say, Australia, may find Australia herself come to possess equal or even more skill in the production of that identical article.

Other things being equal, the division of labor must lead to industries being carried on in those parts of the world best suited to them — *i e*, near power, or near materials. We cannot wonder that a wool-producing country like Australia or New Zealand should aspire to manufacture its own woolen goods instead of exporting its fleeces to be worked upon at the other side of the world and returned to it in manufactured form. We cannot wonder that wood-pulp should be largely made in places where the timber out of which it is made is grown. Only lack of power can ultimately prevent the material being worked up in the place where it is produced; and when the world's water-power is developed, or if new sources of power are discovered, we may see very great changes take place as the result of the further great division of labor.

It is only the setting free of labor by economizing it that enables new tasks to be undertaken. If the raising of food was so laborious as to occupy nearly all the time of the human race, then men and women would be able to command little else but food. As soon as food-raising becomes simpler, a certain number of workers are set free to make homes and to make clothes. As soon, again, as these tasks are lightened, a certain number of people become free to supply further comforts.

Summing up what we have considered in this and the preceding chapter, we see that labor is saved and set free by continuous processes which may be briefly expressed as follows:

1. The storing of the products of labor as capital or stock;
2. The division of labor;
3. The invention of new machinery and processes;
4. The exchange of commodities, which has its roots in the division of labor.

It is important to observe that what we have termed the setting free of labor by the saving of labor need not cause unemployment or distress to any man, but may easily do so through lack of proper social and industrial organization.

Let us suppose that in a given community of a million people there are ten different occupations, and let us distinguish these by the letters A to J Let us suppose, further, that the members of this community, working economically by known methods, are divided up in the following proportions between the ten industries

Industry	Number of Workers
A	100,000
B	50,000
C	125,000
D	200,000
E	75,000
F	50,000
G	50,000
H	300,000
I	25,000
J	25,000
All ten industries	1,000,000

Now let us suppose the community of a million persons to increase to five million, and let us suppose, further, that while the population so increased no labor was saved in any of the ten occupations and that, therefore, each of the ten industries had to employ the same *proportion* of the community as when the community numbered only a million. Then, when the community reached five million, the division of occupations would be as follows:

Industry	Number of Workers
A	500,000
B	250,000
C	625,000
D	1,000,000
E	375,000
F	250,000
G	250,000
H	1,500,000
I	125,000
J	125,000
All ten industries	5,000,000

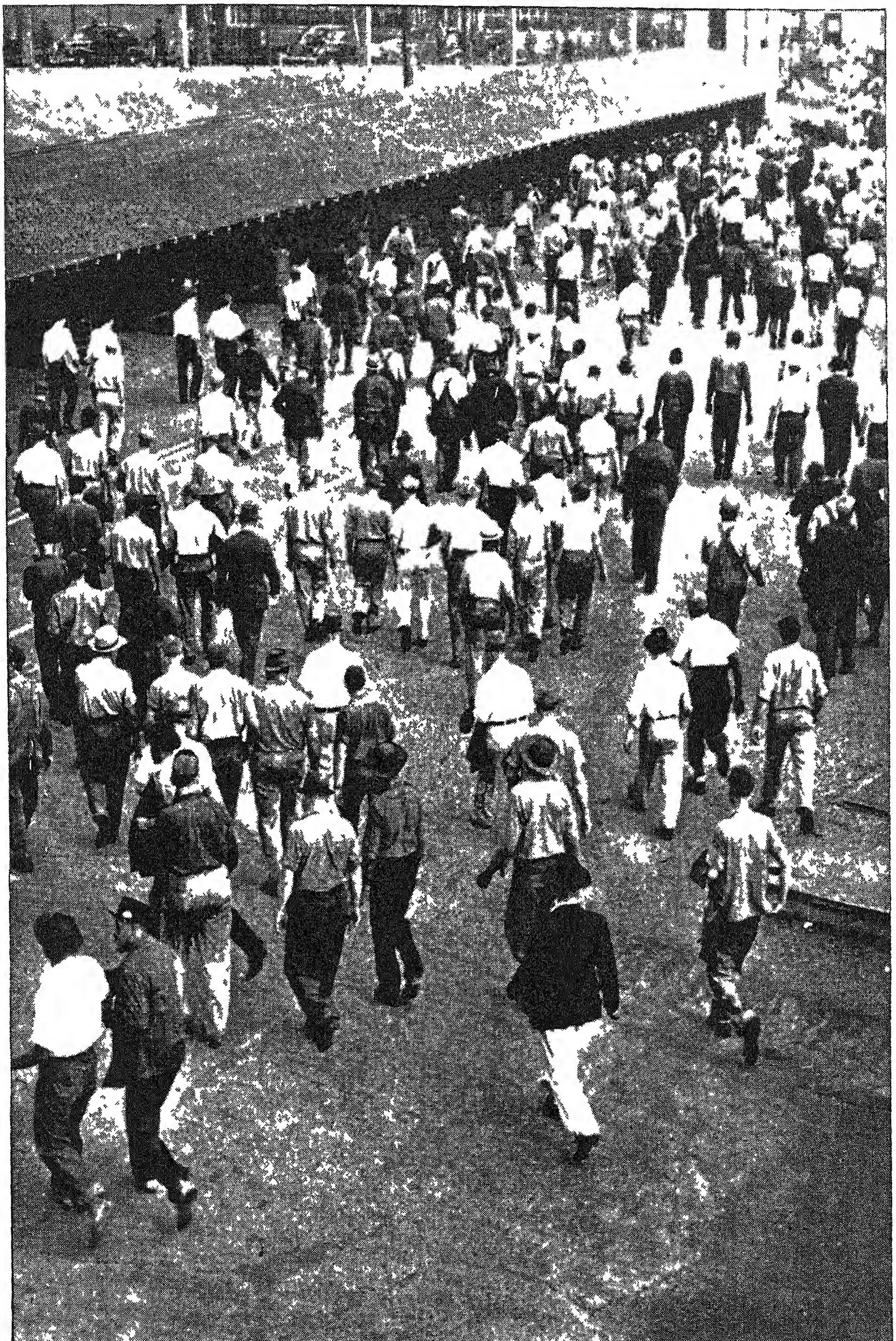
What does this mean? It means that, although the community has multiplied five times, it cannot be a penny better off per individual, because no labor has been saved, and exactly the same proportion of workers is needed for each trade. Not a single new trade can come into existence, because a new trade under the circumstances can only be gained by giving up an old one or part of an old one. No matter how sorely other industries, which we will call K, L and M, may be needed, they cannot be started, because there is not a single worker free to engage in them.

It must be admitted that the example that we have just given is fanciful and even impossible With the growth in the size of industries, there come changes in their organization, increased applications of the principle of the division of labor and further economies. We are not referring here to the increase in the size of the individual plant. This may be economical and advantageous up to a certain point. But the reader will have noticed that the largest industrial establishments he knows are, after all, of limited and fairly definite size. Further growth is accomplished by duplication, by building more plants, rather than by extending old ones. The advantageous size of plants varies, of course, with different industries.

Nor are we discussing agriculture, where, as we have seen, a large increase in product can generally not be secured except at a considerable increase in the cost of production per unit. In agriculture, the "law of diminishing returns" is at work. Larger crops cannot be had without resort either to poorer soils than those already in use, or without the more thorough and intensive cultivation of lands already cultivated. Either alternative means more cost per unit of product.

We are discussing, then, neither agriculture nor the *single* industrial establishment. We are focusing our attention upon manufacturing industries as wholes. Now, within any industry an increase in the demand for its product will almost invariably lead to important economies. For example, even if the only result is to multiply the number of plants, there will be some

MANY HANDS MAKE LIGHT WORK



O E M

Modern factories employ thousands of workers and as a result produce goods in great quantities.

gain, for it may be assumed that there will result a better distribution of plants so that the costs of transportation for the average unit of product will be decreased. In general, however, a growth in the output of an industry as a whole will result not only in an increase in the number of plants, but also in a further *differentiation and specialization* as among the different establishments. When the shoe industry of the United States reached a certain size, it became possible to build large factories specializing in certain grades of shoes, in men's shoes, or women's shoes, or children's shoes. It became profitable to build separate establishments for the making of lasts, and for the making of shoe machinery. With the development of the American iron and steel industry, we have had not merely the multiplication of blast furnaces and rolling mills, but we have had the further development of tube mills, rod and wire mills and mills turning out other finished products of different types. The growth of the automobile industry has been accompanied by the development of specialized industries making motors, bodies, clutches, axles, and other parts.

In short, with the growth of an industry, division of labor as among the different plants in the industry becomes not only possible but profitable, and, because profitable, inevitable. The division of labor and the roundabout methods involved in the machine process, — "the making of machines to make machines to make machines", — are feasible only when there is a market for a fairly large output. With an increase in the market, the possible and practicable economies of the division of labor increase and multiply. No one factory can afford to equip itself with a large outfit of special machines and tools unless it is assured of large sales for its products. With only a small market, the slower and most wasteful methods of direct production, involving less "roundaboutness", less division of labor, must persist.

But these considerations, important as they are, do not lessen the significance of the fundamental truth that a new industry can be started in a country only by freeing labor from an old industry.

Every inventor, therefore, who displaces labor is a servant of mankind. Every business organizer who shows how one man can do the work which two men used to do increases the wealth of the world.

But while all this is true, it is also true that for a specific individual a new invention may spell disaster and ruin. If to-morrow an inventor were to produce a house-painting machine which would apply paint to wood-trim, walls and floors as well as it can be done by hand, but with only one-twentieth the amount of labor, then a very large number of house-painters would be thrown out of work, and they would suffer severely. The cheapening of house-painting would lead to more such painting being done, and this fact would reabsorb some of the displaced labor. The community as a whole would benefit considerably; and children growing up into new workers, not being required so much for the house-painters' trade, would be able to engage in new occupations. But a certain number of aged or aging house-painters would permanently suffer, and in some cases might even be reduced to want.

The loss to the individual by changes beneficial to the community

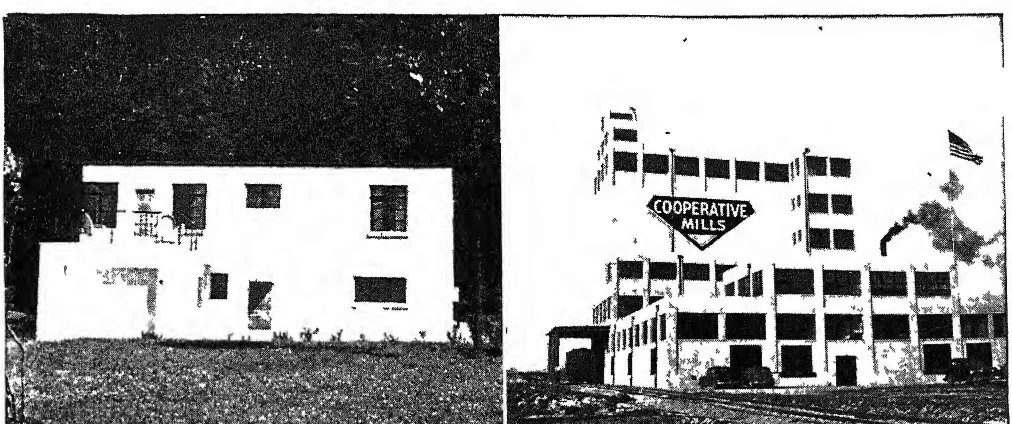
We see, therefore, that while it is quite necessary for the progress of society, and for the increase of the wealth and comfort of the community, for labor to be continuously and progressively displaced and set free to engage in new occupations, what is on the whole and in the long run a beneficent process is attended for a minority of individuals by quite undeserved loss and, possibly, acute suffering.

If the community as a whole thoroughly understood the importance of the matters of which we have been speaking, it is surely clear (1) that they could not stand in the way of new inventions, and (2) that they would see to it that there should be no individual loss through the application of new inventions. It is not impossible, it is not even difficult, to make social and industrial arrangements by virtue of which men who are thrown out of their trade by the march of invention may be tided over until they can find a new employment.

When our organization has reached a higher degree of development, the essential truth, that the object of trade and of industry is not to make work but to create a plentifulness of utilities with the least possible amount of work, will be realized, and, when it is realized, few difficulties will stand in the way of its accomplishment. To this we must add, however, that the provision of work which shall in itself be pleasurable, which will afford an avenue of self-expression for the workman, which will unleash his energies, enlist his interests, and enrich his life, is, in itself, an object of social policy comparable in importance with the provision of a plentiful supply of utilities. We may increase utility by the simple, even if difficult, device of making work itself less of a disutility.

Nothing can ever make the attendance upon machinery a task fit to be prolonged in all cases for many hours at a time. How, then, is civilization to cure itself of the evils which can so easily arise from the use of machinery? How is it to retain the advantage of cheap production while obtaining for the individual a proper recreation of faculties? The answer appears to be that, when work comes to be thoroughly organized, what machine-work will be necessary will be so devised and so distributed that no member of the community will be reduced to the rank of a machine tender for any considerable length of time. We cannot abolish the machine; it would be foolish to abolish the machine. Civilization must, however, abolish the machine slave. Attendance upon machines would be a different matter if it were so reduced to a thorough economy, and so shared as a social duty, that no man or woman had to do more than man or woman can bear without losing his or her well-being.

The most practicable method, however, of lessening the evils of the machine system is to bring about a more thorough utilization of that system. The routine work of machine tending, where it is work of a kind that does not enlist the interests and imagination of the workers, is itself precisely the kind of work which may itself be reduced to a machine process. The engineer, the foreman, the man in responsible charge of a complicated machine, finds in his work a plentiful opportunity to develop his own interests and powers. The kind of machine tending that, from a social point of view, must become unendurable is the kind in which the worker becomes frequently a *part* of the machine, repeating a simple and monotonous physical movement minute after minute, hour after hour, and day after day. It is just these small routine movements which, with the perfection of the machine process, may be delivered over more and more completely to machinery. One way, perhaps the most important way, out of the admitted evils of the machine system is through the more thorough utilization of the possibilities of that system.



Courtesy The Co-operative League

LEFT, CO-OPERATIVE HOUSING PROJECT, MADISON, WISC. RIGHT, CO-OPERATIVE MILL, READING, OHIO.

EVOLUTION OF THE TYPEWRITER

Development of the Machine That
Does the Work of Hundreds of Pens

SPEEDING UP BUSINESS CORRESPONDENCE

SO accustomed are we to the many ingenious devices of this prolific age of invention that it is doubtful if even yet we fully appreciate the convenience of the typewriter. It is only by pausing a moment to compare the easy, rapid and legible work of the modern typist with the slow, laborious efforts of the ancient scribe that an adequate conception can be gained of the wonderful progress that has been made in the methods of recording thought and of facilitating the interchange of ideas. When the first practical typewriter was produced, no one realized how completely it would revolutionize the world's business methods. No one dreamed — not even its inventors — that it would expand the operations of business as the locomotive and steamboat had extended those of transportation; that it would not only provide a new profession for the young men and women of America but of the entire world. In a period of less than fifty years with the typewriter, the business world has advanced farther than it had in as many centuries without it. The busy man of affairs is no longer compelled to put down his ideas in handwriting or to decipher the illegible scrawl that invariably results from the haste and press of active business, nor does he lose the many excellent ideas that are crowded from his mind before he has time to record them. The modern typewriter has supplied a means of making correspondence easy, quick and legible. By economizing the time of the thinker and writer no invention has appeared since the art of printing that has done so much to promote the general spread of intelligence as the typewriter. Many of our great inventions have been the result of accidental discoveries — the by-products of thought and experiment seeking other results in a more or less related line of investigation. So it was largely the efforts of early inventors to produce devices for making embossed letters for the use of the blind, and to perfect telegraphic printing machines that gave impetus to the idea of a writing machine. Such important inventions come into existence by slow stages of development and many acute minds were destined to combine their efforts before a successful writing machine was devised. The typewriter had been in process of evolution for more than a century and a half before that, but in recording the real history of its progress it is not necessary to go beyond the last half century, as it is within this period that the first practical machine was produced and the present high state of perfection reached. It is true that some successes were attained at an earlier date, but these served principally in contributing ideas for subsequent inventors to develop, enabling them to accept the practical and discard the unpractical.

Phonography, that is, the representation of words as they are pronounced (from the Greek words meaning "sound" and "write"), was one of the great inventions of the nineteenth century, a phonetic system of shorthand having been introduced by Isaac Pitman in 1837. As is the case with most inventions, few appreciated its value in its early stages. It is commonly understood as stenography.

The latter, however, is an abbreviated form of writing and was in existence centuries before the system of sound writing was invented. By the aid of shorthand the business man and the writer were enabled to speak their thoughts to some one else instead of laboriously writing them out themselves; yet shorthand was but a halfway measure. The stenographer could take letters or manuscript as fast as they could be dictated and could save the employer much time, but could not transcribe what he had taken any faster than he could drive his pen. Something more was needed — something that would actually cut the time of writing to one-half, one-third, one-quarter, according to the skill of the writer. Hence, the typewriter was required to perfect the scheme that has so efficiently economized the time of thinker and writer.

The earliest evidence of an attempt to produce a typewriter is found in the records of the British Patent Office. According to these records a patent was granted in the year 1714 to Henry Mill, a noted English engineer, for a machine intended to do writing. In those times it was not customary to attach drawings to patents, so that no more is known about the device than what is briefly described in the specifications, namely, that it was a device intended "for the impressing or transcribing of letters singly, or progressively one after another, as in writing, whereby all writings whatsoever may be engrossed on paper or parchment so neat and exact as not to be distinguished from print." But the brief description is sufficient to show that Mill's invention embodied the fundamental conception of the typewriter as we know it today. No record of the construction of this machine has ever been found, so that we must conclude that, like many other important inventions, this early attempt was abandoned and that the idea passed entirely out of mind with the inventor and was not revived until many years later. In 1784 a machine was invented for the purpose of embossing printed characters for the blind. Of this machine, also, nothing is now known, and its importance is doubtful.

The first American typewriter

The first American typewriter of which we have record was the invention of William Austin Burt, of Detroit, who in 1829 took out the first United States patent ever issued for such a machine. It was called a "typographer". The letters of the alphabet were arranged on a segment and corresponding notches acted as an index. A lever which could be worked up and down and also moved laterally was provided with a series of type arranged in a segmental curve so that any type could be brought into place on the paper by swinging the lever around and down into the proper notch in the index segment. Although an actual working typewriter, it was of the roughest construction and crude in the extreme. The record of this patent, together with the original model of the machine, was destroyed by fire in 1826, but a restored model and a copy of the patent is now to be found in the United States Patent Office.

First machine with separate key levers

To Xavier Progin, of Marseilles, belongs the distinction of inventing the first organized typewriter in which separate key levers were provided. It was called a "typographic machine" and was patented in France in 1833. This machine was also crude in design and awkward to use. Upright key levers were arranged around a circular plate, and pivoted to the shanks of type hammers, to raise and lower them. The hammers were inked from a pad and delivered a printing below on the paper which was held stationary below the machine. The whole nest of levers was moved over the paper as each letter was printed.

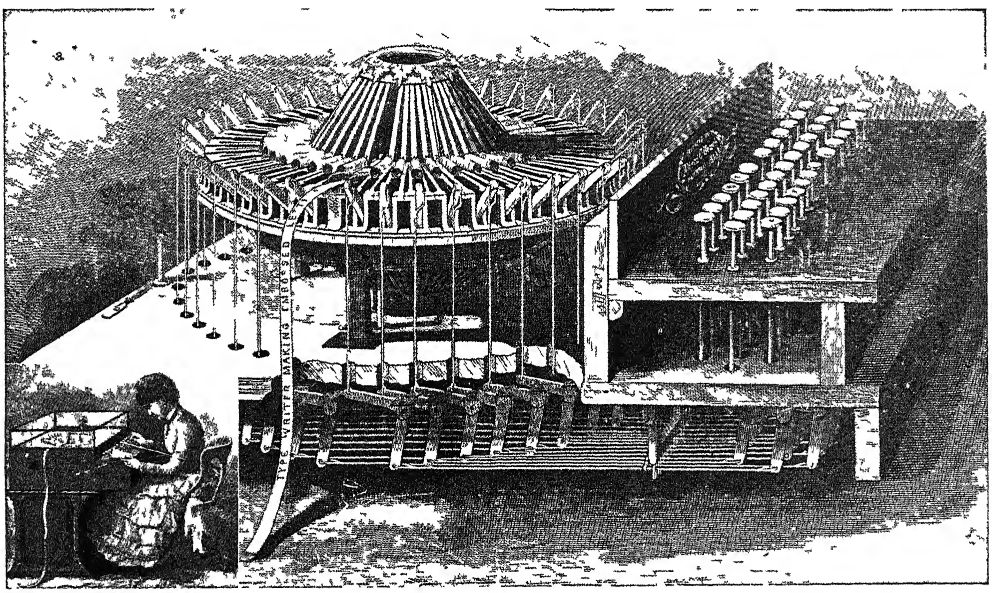
In addition to printing letters the device is said to have been used for printing music and for making stereotype matrices. The records of the British Patent Office show that in 1840 Alexander Bain and Thomas Wright made application for a patent on a machine for use in connection with the telegraph, and these men were afterwards known as the inventors of a telegraphic printer. Bain's device proved to be of no use as a typewriter.

Between 1840 and 1850 several type-writing machines were invented in England, but, like many of the earlier efforts, they were designed primarily for producing embossed letters for the blind, or, more especially, for purposes of the electric telegraph, and, as such methods of telegraphy were soon superseded, these inventions attracted little attention. These machines embodied some of the principles of the modern typewriter, but none of them passed beyond the experimental stage.

In America, however, Charles E. Thurber of Worcester, Massachusetts, invented and patented in 1843–1845 a machine that did actual work. This was a type-wheel machine operated by a combination of type bars around a large circle. It was large and clumsy, but it is entitled to much credit for having suggested the first principle of the movable carriage, a feature embodied in all modern machines. This machine was slow but it did fairly good work and the original model is now on exhibition in the hall of the Antiquarian Society at Worcester.

Perhaps the inventor who aroused the greatest interest about this time was Alfred E. Beach, editor of the *Scientific American*, who during the period from 1847–1856 did considerable experimenting in an effort to produce a practical typewriter. His machine amounted to little, but the articles which appeared in the *Scientific American* gave impetus to the movement and encouraged later inventors.

The principal novelty of Beach's machine was the converging type bars to a common center, and this feature has been employed in many of the machines invented since that time. It had other good points, such as the letter and line spacing, paper feed devices and line signal bell, and showed marked improvement over previous machines.



From *Scientific American*

THE ORIGINAL TYPEWRITING MACHINE
Which was awarded the gold medal of the American Institutes in 1856

Beach was followed by S. W. Francis, a wealthy physician of New York, who took out a patent for a typewriter in which a motion similar to that of a piano hammer was employed to throw up the types, which were arranged in a circle, to a common center. Thus to the Beach principle of a circle or nest of type bars, Francis added the pianoforte action. The machine was intricate and cumbersome, and although capable of good work, was too costly for commercial venture. It was never put on the market, and indeed, so far as is known, but one model was ever constructed.

In 1843 Pierre Foucauld, a young blind man of the Paris Institute for the Blind, produced a machine which was very successful in printing raised letters. Foucauld's typewriter attracted much attention and was awarded a gold medal at the World's Fair in London, in 1851. Several of these machines were constructed and used for a long time in various institutions for the blind in different parts of Europe. They did not come into very general use, however.

The writing ball; a curiosity in the history of typewriting invention

One of the most peculiar typewriter inventions known in Europe was the writing-ball, invented by a clergyman of Copenhagen, a Dane named Hansen. This machine consisted of a hemispherical brass shell inverted over the paper-carrying and spacing mechanism. Through this shell radiated a number of rods from different directions toward the common printing point which was the center of the sphere. The machine was light and small and did good work but it was too costly and too slow in operation for commercial success. United States patents were issued upon this machine in 1872, and in 1876 it was awarded a gold medal at the Centennial Exhibition in Philadelphia. However, it is known in this country only as a curiosity.

Business growth in the last century urgently demanded an efficient machine

Numerous patents were issued from time to time representing various attempts to produce a machine that would be acceptable to the public, but none of these up to 1867 demonstrated any marked progress toward a practical typewriter. A writing machine had not yet come to be regarded as of any special value to the business world, as business had not assumed its subsequent huge proportions requiring the aid of such a device. But when the wonderful progress and prosperity of the latter part of the nineteenth century necessitated a radical change in business methods, our men of genius were equal to the task, and its production was not long delayed.

The man who first brought out a practical typewriter and made it indispensable to the modern business world was Charles Latham Sholes of Milwaukee, who in 1868 took out patents on models which formed the working basis of the first typewriter that ever went into office use. Associated with Sholes, who was a printer and editor, was Samuel W. Soule, also a printer, inventor and farmer, and Carlos Glidden, who at that time was engaged in an entirely different field of invention. Sholes and Soule were jointly engaged in the construction of a machine for serially numbering the pages of blank books, etc. The three men were thrown in daily contact in the same machine shop in Milwaukee in which they were having their experiments conducted, and each evinced a keen interest in the other's inventions. It is said that Glidden one day chanced to remark, "Why cannot such a machine be made that will write letters and words instead of figures only?" In this way was the seed of thought dropped without any knowledge at the time that such an invention had ever before been attempted. The suggestion did not bear fruit immediately, but in view of subsequent developments it may be said that in this casual remark the Remington typewriter had its origin. Not long after this Glidden discovered quite by accident that a machine had been invented by John Pratt of Centre, Alabama, which was designed to do just what he had suggested. He was impressed with the great benefit to mankind which a machine of this kind would confer, as well as the fortune awaiting the successful inventor. He brought this to the attention of Sholes, and it strongly appealed to his imagination. Sholes determined to try what could be done, and as Glidden had first suggested the idea he was invited to join in the enterprise. Finally the aid of Soule was also enlisted. Numerous experiments were made and many devices suggested. Eventually a crude model was constructed which was largely the work of Soule, who suggested the pivoted types set in a circle, and other minor details. Sholes contributed the letter-spacing device.

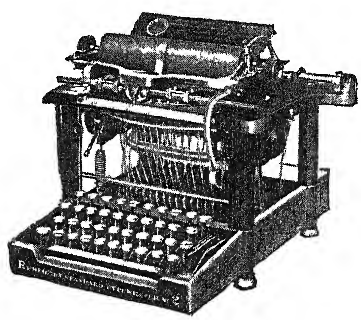
These machines were placed before the public under the management of the original inventors, but Soule and Glidden eventually withdrew from the enterprise. At first the machine used only capitals, and while fairly accurate and rapid, soon showed that it was far from being perfect.

Original Remington Model No 1, exhibited at the Centennial Exhibition in 1876, where it attracted much attention but was slow to gain public favor. It wrote only capitals

Many letters were written on it, and one of these happened to fall into the hands of James Densmore, a wealthy oil and iron man of Meadville, Pennsylvania. Recognizing the great future for such a machine, he purchased a fourth interest from the inventors, paying all the expenses incurred in experimenting up to that time. He made this investment without having seen it, basing his judgment on the fact that it would print legibly and do faster work than the pen. After seeing it, months later, he pronounced the manner of construction a failure but the principles embodied to be correct, and he immediately set about developing them. Numerous models were built and condemned, which discouraged Soule and Glidden to the extent that they withdrew from the enterprise, and had it not been for the constant encouragement of Mr. Densmore, Sholes would have done likewise. After the machine had been perfected to the point that the owners were willing to submit it to the public upon its merits, it was decided to secure the opinion of a disinterested expert mechanic in regard to it and its further development and manufacture.

For this purpose George W. N. Yost was selected, and after suggesting a few minor changes, which were made, he recommended E. Remington & Son of Ilion, New York as doubtless best prepared for doing such exacting work as was necessary in constructing the interchangeable parts required. This firm having been engaged in the manufacture of munitions for the Civil War was well equipped with machinery and skilled workmen, and, after making various changes and improvements, built a thousand machines. They also secured the rights to the machine, to which they gave the name Remington. This transaction took place in 1873, and the first model of the Remington typewriter was put on the market the following year.

The manufacture had been arranged for but the distribution was another matter. The public, not being familiar with the typewriter, had to be educated as to its value, and more than a decade passed before it began to really appreciate its possibilities. The first Remington attracted much attention at the Centennial Exhibition at



REMINGTON PROGRESS

Remington Model No 2, awarded a gold medal at the Paris Exposition of 1878 This machine wrote both capitals and small letters without increasing the size of the keyboard or adding to the number of type bars

Philadelphia in 1876. One of the objections to it was the fact that it wrote only capitals, but this difficulty was soon overcome. Lucien S. Crandall conceived the idea of a shift key and Byron A. Brooks that of having two types on one key, a capital and a small letter. The combined ideas of these two inventors made it possible to write both small and capital letters, together with numerals

and other characters. This was accomplished in 1877. The machine manufactured meantime by Mr. Yost, known as the "Caligraph", was a double-case machine — that is, it had a full keyboard, capital and small letters, with a key for each type, the capitals being divided and arranged without regularity on each side of the keyboard. This machine was less popular, but it contributed greatly to the development of the use of the typewriter, as it created the competition needed to arouse public interest.

The No. 2 Remington, which was awarded a gold medal at the Paris Exposition of 1878, was the first machine containing the upper and lower-case characters, and was followed by other models, each very similar to its predecessor but each showing improvements and refinements. The No. 2 had 38 characters; the No. 6, 76 characters; the No. 5, No. 7 and the wide carriage machines all had 84 characters.

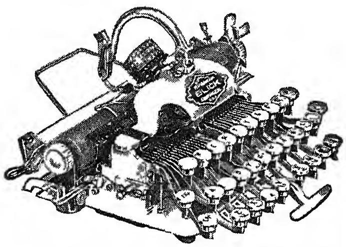
THE HAMMOND, OF CONVENIENT PORTABILITY

The arrangement of the original keyboard was influenced by the fact that Sholes was a printer, and he designed it after the printer's case. But this was found impracticable, as in many instances the type interfered in action to and from the printing point. When the necessary changes were made it was found possible to write to the extent of the one-finger operator's ability, and the manufacturer settled down to that style of keyboard. When the idea of systematic writing by touch was conceived, numerous authors introduced different systems, but all based upon the same arrangement of keys. As the advantage of touch typewriting became apparent, a universal keyboard was found desirable, so that the typist could change from one machine to another without change of system.

Radically different in theory and construction from other writing machine inventions up to this time was the Hammond typewriter, invented by James B. Hammond in 1880–1883. Its central principle was the type-wheel, and the difficulty involved in its construction was in the great mechanical accuracy required in order to get the hammer blow delivered at the exact moment that the desired type reached the printing point. The advantage of this construction was that each wheel contained a full set of type and could be quickly changed, enabling the use of various languages and styles of type on the same machine; hence it found a niche in the business world. The wheel has been changed to a shuttle and carries two sets of type. The ideal keyboard for the accommodation of the characters on the shuttle was submitted to the public, but it was not liked, and the universal keyboard was adopted. The Hammond was the first successful type-wheel machine. Its touch was uniform, as was the blow delivered by the hammer, but great speed was not possible except on certain characters.

A wonderfully ingenious little machine is the Blickinsderfer, which is mentioned at this point because it is a type-wheel machine embodying the same principle as the Hammond. This machine did not use a ribbon, but the wheel, in its movement toward the printing point, passed a felt pad from which it obtained its supply of ink. The Blickinsderfer was popular because it was low priced, easily portable and did good work; and the type-wheel, containing different styles of type or char-

acters of other languages could be changed with little difficulty. The manufacturers also tried to introduce a keyboard adapted to the arrangement of the characters on the wheel, but were compelled to adopt the universal keyboard.



ALUMINUM FEATHERWEIGHT BLICK-INSDERFER

The "Bar-Lock" was the next double keyboard machine to follow the Caligraph. For it was claimed visible writing, which was beginning to be demanded, but the writing was not really visible, the operator being compelled to lean forward and peer over the type levers, which was more inconvenient than to lift the carriage to see the work, as was necessary with the other machines that made the impression beneath the printing platen.

The Smith-Premier, placed on the market about 1889, was one of the next succeeding machines, and proved to be very effective not only because of its construction and good work, but because of the method by which it was marketed. This machine was of the double keyboard variety, that is, a key for each character, but it differed from the Caligraph, and was an improvement over it, in that the keys in both the capital and small character cases were arranged alike, one just above the other in the same relative position. The bearings of this machine were long, which helped to preserve the alignment, and the platen tilted forward, when it was desired to see the work, which was more convenient than the old way of lifting the carriage. This machine was provided with an automatic ribbon reverse with an arrangement for the use of a tri-colored ribbon which might be shifted by a lever from one color to the other, and with a convenient means of cleaning the type. By removing the platen, an easy operation, and inserting a crank handle down in the type-well, connection was made with a circular brush, which was always in position. The turning of the crank raised the brush and all the type were effectively cleaned at one time. This was a great improvement over the old way of raising the carriage and lifting each key, individually, in order to brush it, resulting not only in soiling the hands, but also in frequently missing some of the type.

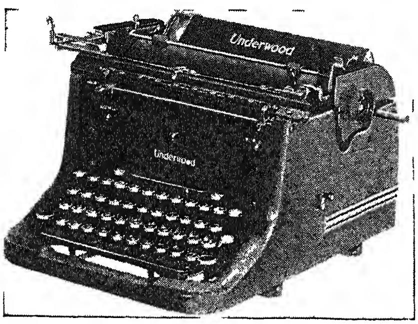
There had been a number of attempts up to this time in the development of the typewriter to obtain visible writing, and many manufacturers had tried to obtain it, but without any great success: for example, the Bar-Lock, already referred to, with its leaning of the operator's body forward instead of a hand movement to raise the carriage; the Hammond, which required pushing down the ribbon control to see what had been written; the Williams, the type-bars of which had what was known as the "grasshopper" movement, coming from each side of the platen and giving but one visible line which immediately passed from view; the Oliver, invented about 1893, which showed the last ten characters written, but necessitated the movement of the carriage back and forth to see the full line or more. None of these methods was satisfactory.

About 1894 Franz X. Wagner, who had been associated as an inventor with the typewriter industry since its earliest days,

THE FIRST "VISIBLE WRITER"

invented a type-bar mechanism which provided for a front stroke. The earlier machines had been manufactured on the principle of the under-stroke, that is, making the impression beneath the cylinder, out of sight. Later manufacturers who

sought to produce visible writing made their type-bars strike downward on top of the cylinder, but each possessed mechanical difficulties which prevented the typist from seeing the writing. The invention of Mr. Wagner not only greatly simplified the construction of the machine, but made it possible to see every character written on the page and kept it constantly in sight, from top to bottom. Mr. John T. Underwood, from whom the machine which embodied this improvement gets its name, secured the controlling interest in it and immediately set about refining and developing it. The front-stroke machine reversed the old and established new basic principles in typewriter construction. In addition to giving completely visible writing, the type lay in a semicircle, face up, just above the keyboard, where it could all be thoroughly



THE UNDERWOOD "MASTER"

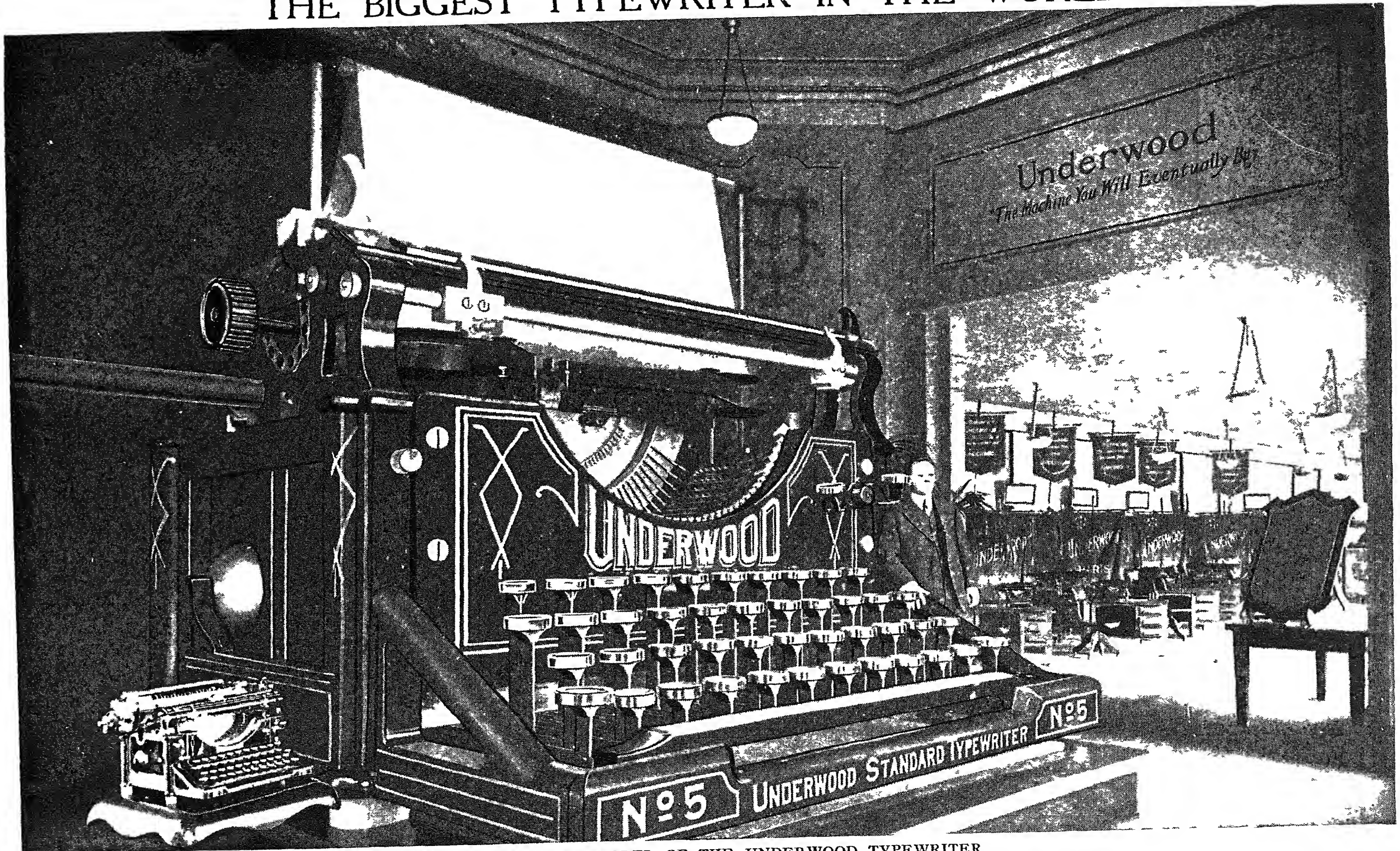
cleaned with two or three strokes of the brush. These type-bars hang in a segment on a single steel type-bar bearing. They strike upward into an adjustable guide and the type-bars may be removed instantly, the bearing cleaned and the bars returned without interfering with the alignment.

The complete visibility of writing, as well as other features, the value of which was immediately recognized by the public, caused the Underwood to meet with instant favor, and led to a remodeling of all the leading typewriters to secure the same end. The extent to which the public appreciates the typewriter today is indicated by the fact that one of three plants of the Underwood Company has a floor space of twenty acres.

Every improvement is introduced to promote system and convenience in construction. In the best factories it is divided into sections, and the work is done with such accuracy that should a defect develop several years after the machine has been sold, the cause can be traced to the individual responsible for it. As the average typewriter is composed of 3000 odd parts, an almost infinite variety of mechanical operations are necessary before a complete machine goes forth from the factory in perfect working order. First the main framework which supports the mechanism is cast in one piece in a foundry in which unusually high-grade workmanship is required. After a thorough cleaning, in which all imperfections incident to molding have been removed, the frames are sent to the transferring department, where they are given the required finish and where decorative work, the name and style of machine or other printing, is transferred to the finished surface by means of stencils.

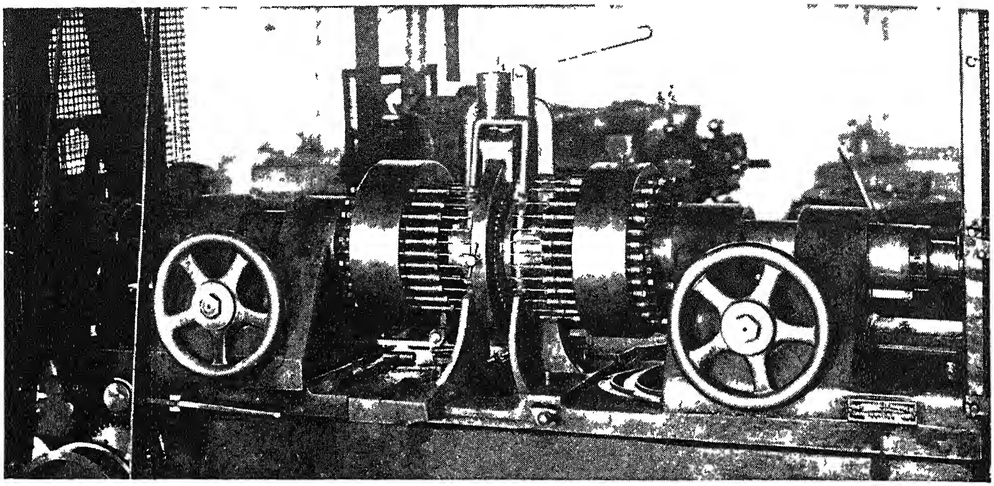
To each frame is given a working or shop number, a card is attached to it, and the part that each employee plays in its construction is indicated by his signature on the card. When the machine is ready for sale the selling number is placed thereon, thus making it difficult for a stolen machine to be hidden any length of time, as the secret or shop number will indicate the identity of the machine although the sales number may have been defaced. While the frame is in process the heavier parts of the mechanism which the frame supports are being formed by punching machines in the heavy punch press room, while the smaller and lighter pieces, some of most intricate design, are turned out in immense quantities on the lighter punch presses and in the automatic screw-machine department. So skilfully made and accurate are the dies used in the punching machines that the many small parts fit into their places in the machine without further operations being performed upon them. A few of the parts, however, such as the type-bar ring, require certain milling operations before they are ready for assembling.

THE BIGGEST TYPEWRITER IN THE WORLD



GIANT WORKING MODEL OF THE UNDERWOOD TYPEWRITER

The man at the right and the ordinary No. 5 machine at the left give an idea of its size. It writes only capitals, and the pressure required on each key is the weight of a man. It is used on posters, but is of course really for advertising purposes

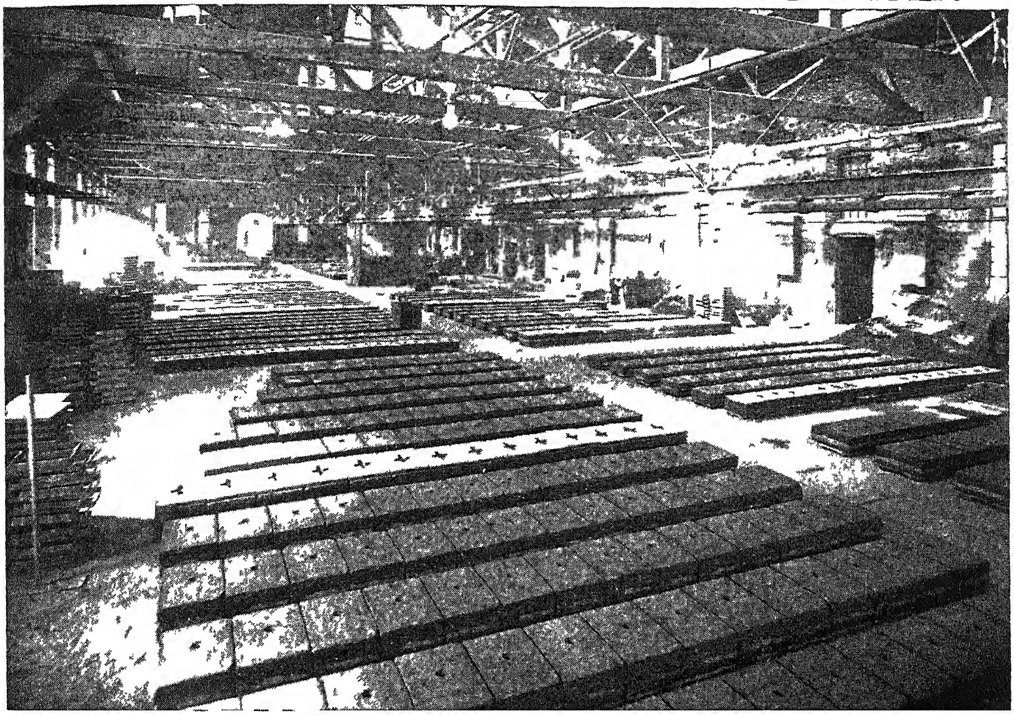


ONE OF THE REMARKABLE MACHINES WHICH AUTOMATICALLY DRILLS THE FRONT AND BACK SEGMENTS OF THE TYPEWRITER MECHANISM

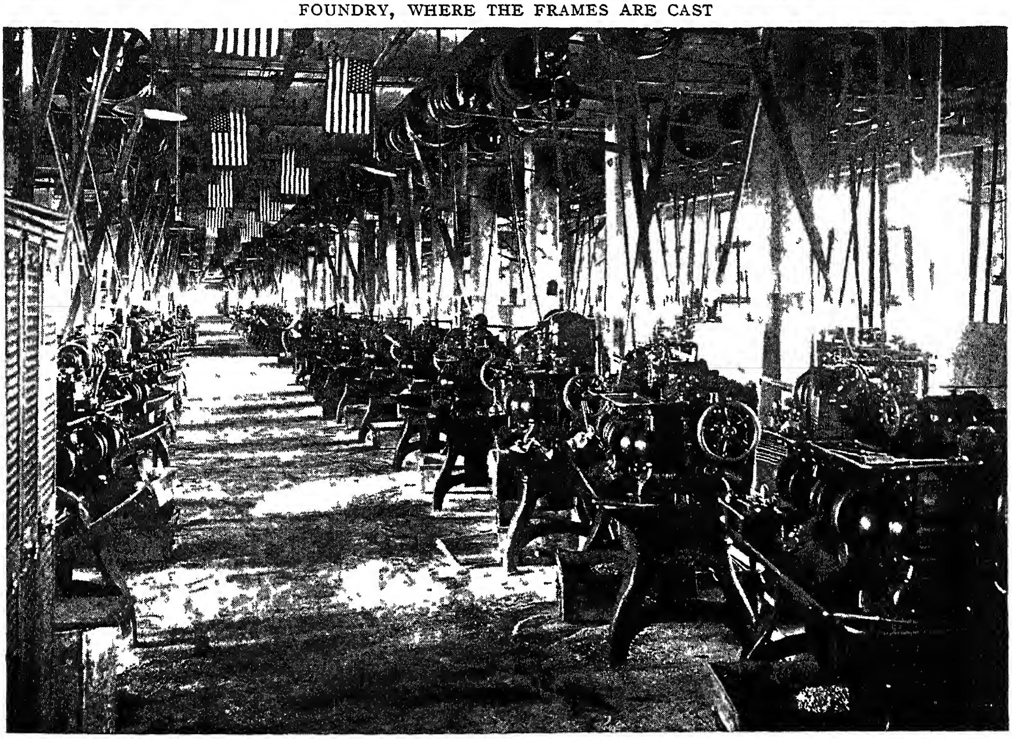
It is interesting to note that the many small parts of which the typewriter is composed are produced almost wholly by automatic machines. Small screws, pins, rivets, etc are automatically produced from bars or rods of metal fed into machines which seem almost human in their operation Among the most remarkable machines to be found in a typewriter factory are those which automatically form the various kinds of type required on the modern typewriter. Characters of great variety and in many languages are accurately formed in large quantities and with such ingenious mechanical movements as to astound the observer. The most delicate and accurate work required in making a typewriter is that which has to do with the ball-bearing joint of the type-bar mechanism. It is estimated that ninety-eight per cent of the operator's time is consumed in tapping the keys, shifting to write capitals and returning the carriage to start a new line. As friction and wear would otherwise develop, each of these operations is made easier and more accurate by the use of ball bearings. The machines which form the runways in the type-bar ring with such extreme accuracy and those which form the small hardened steel balls and sort them to limits of one ten-thousandth of an inch, are among the most wonderful that can be found in any industry.

It is evident that a machine composed of so many small and intricate parts could not be conveniently assembled by bringing together all the parts in one place and placing them in their relative positions As the various parts are completed in the factory, they are removed to the stock-room and systematically grouped in such a manner that they can be conveniently secured as needed for the assembling operations From the stock-room the parts are sent as needed to the room where the typewriter is assembled into its elements In this minor assembling great skill is essential and many ingenious devices for performing these operations are required. The assembled parts are next passed to the erecting room, where the machine as a whole is put together. After the final assembling the machine must be carefully tested, adjusted and inspected before being packed for shipment. Perhaps the most interesting process which the typewriter must undergo at this stage is that of exercising the keys. It is connected up with an ingenious mechanism which causes each key to be struck many hundreds of times just as it would be struck by the operator in actual use.

Typewriters are now constructed for practically every purpose, their field of usefulness having been extended to include bookkeeping by the development of a machine adapted for writing on the page



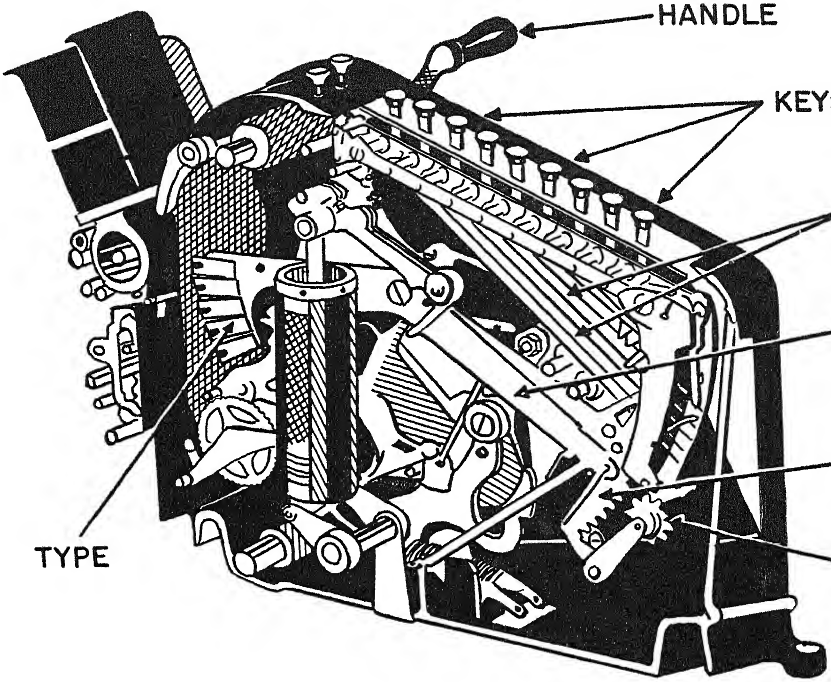
FOUNDRY, WHERE THE FRAMES ARE CAST



AUTOMATIC SCREW MACHINE DEPARTMENT

Where the hundreds of small parts that go into the make-up of a typewriter are automatically produced in immense quantities and with great rapidity and accuracy.

HOW THE ADDING MACHINE WORKS



Both photos on this page Burroughs Adding Machine Co

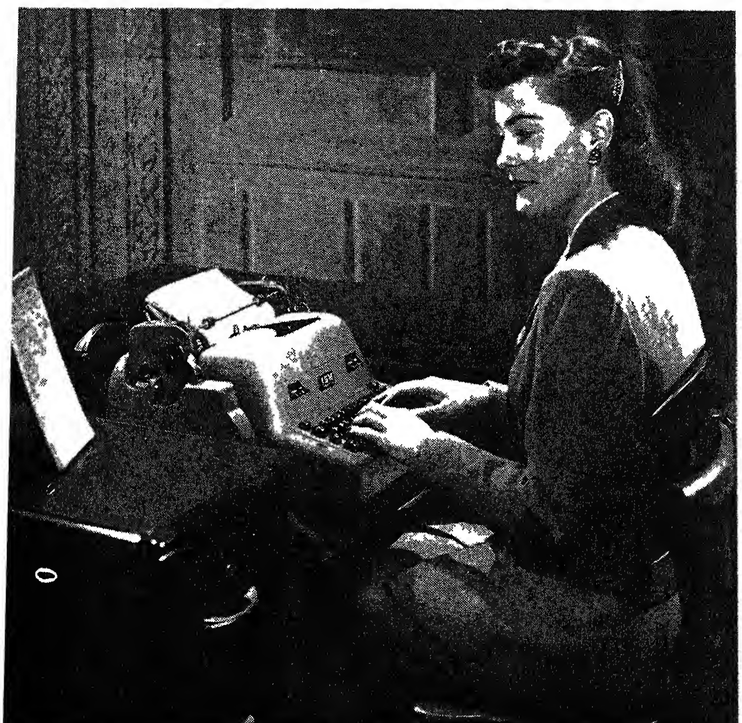
Above is shown a diagram of the working parts of an adding machine When a key — say the 5 key — is depressed and automatically locked the index bar connected with it stops the adding rack at the fifth notch As the handle moves forward, the adding wheel is drawn away from the adding rack As the motion of the handle continues, the adding rack descends until it is stopped by the index bar, connected with the depressed key The rear end of the sector, pivoted to the adding rack, has been moved upward by the descending adding rack until the number "5" on the type is in printing position opposite the printing roll A firing mechanism is released and the number is printed on the paper When the handle is released and travels backward the adding wheel is turned five notches, corresponding to the five notches traveled by the adding rack As the handle comes to rest, the "5" key and the index bar connected with it returns to the normal position If the "4" key is depressed, the number "4" is printed on the paper The adding wheel is turned four more teeth, or nine teeth in all Suppose now that the "Total" key is depressed A forward movement of the handle will print the total "9" on the paper, and the return movement will bring back the adding wheel to zero It is now ready for the next addition

Below adding machine whose working parts are shown in diagram

TWO MODERN KINDS OF TYPEWRITERS

The Vari-Typer provides a variety of changeable type sizes and styles Each of these consists of a little arch of metal faced with ninety characters, it can be inserted in the machine or removed in a few seconds An automatic mechanism permits copy to be written with an even, or squared right hand margin, just as in printing

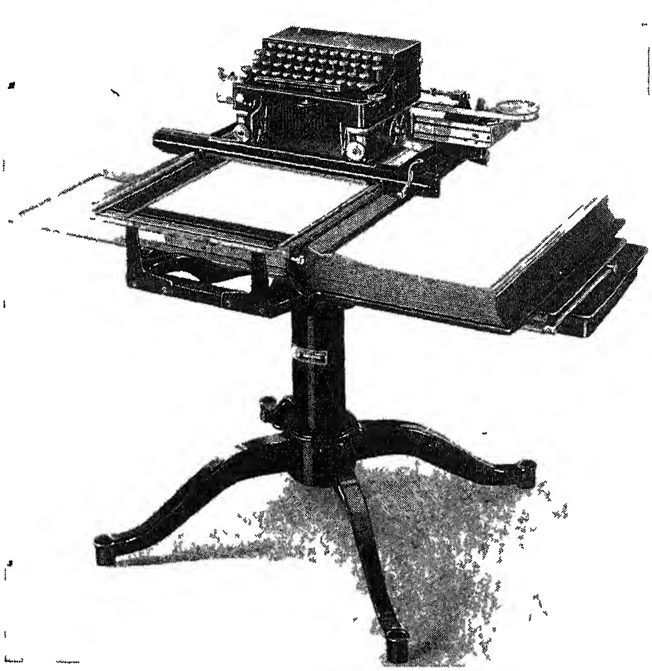
Ralph C Coxhead Corp



Speed and ease of operation are furthered by the use of the electric typewriter All the heavy operations on a typewriter such as returning the carriage, tabulating, back spacing and shifting for capitals, are handled by the touch of a finger The letters produced are uniform since they are not affected by the operator's touch

International Business Machines Corp

of a bound book, such as a ledger. The first machine of this type was the Elliott & Hatch book typewriter. In the operation of this machine the page of the book is clamped between the platen and an open frame which holds the paper smoothly in a stationary position. The machine proper, consisting of frame, type levers, etc. slides on this frame and moves up and down so as to space the lines properly, the keyboard with the type-bars, ribbon, etc. traveling step by step across the page. A great deal of ingenuity has been expended upon devices of this nature, with the result that we now have modifications of ordinary typewriters whereby tabulating and adding mechanisms are supplied so that not only billing and tabulating, but all commercial bookkeeping can be done on the machine used for ordinary correspondence. The Elliott-Fisher billing and adding machine, patented in 1906, one of the first of these, is a refinement of the Elliott & Hatch book typewriter.

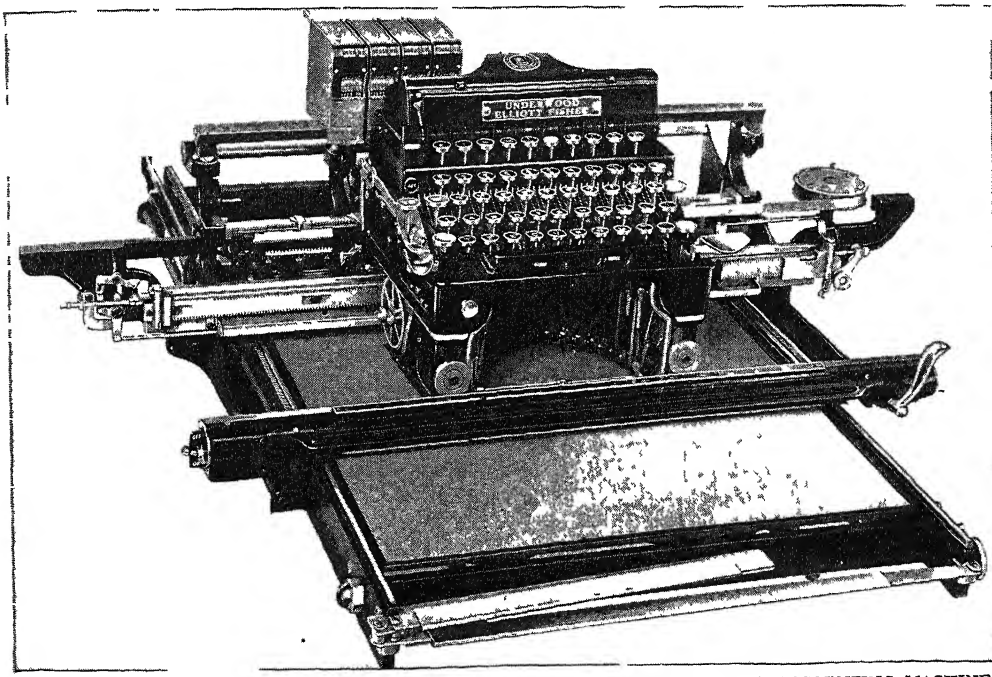


THE ELLIOTT-FISHER BOOK-RECORDING MACHINE
By means of its flat writing surface and a special ribbon, this machine typewrites permanent records in bound books.

The first Underwood typewriter contained the first basic principle of the tabulating device, which has added materially to the ease with which tabulating and statistical work so necessary in bookkeeping can be done. In 1907 the Remington adding and subtracting machine appeared, and was followed in 1915 by a most elaborate and highly perfected machine. Other makers have brought out similar bookkeeping and adding and subtracting typewriters for which certain advantages are claimed. These latest and most recent developments of the typewriter have completely revolutionized bookkeeping and accounting, for these remarkable machines are able to list the items and to add, subtract or cross add. In addition, manifolding is readily and conveniently secured by adapting the work to the ordinary copy press; the use of carbon paper for making several copies along with the original, or by the use of a special kind of wax sheet stencils may be made whereby an indefinite number of copies may be secured on a mimeograph machine. This is a feature which is now indispensable in dispatching the vast volume of correspondence involved in modern business. Among the more recent adjuncts devised for facilitating correspondence with the typewriter may be mentioned the use of the phonographic dictating machines, whereby any qualified typist is able to transcribe letters or other spoken communications dictated into the machine at some previous time.

Power typewriters have been produced in which the impression mechanism is operated by magnets or, as is more usual, by motors, when the operator closes the circuit by touching the key. The advantages claimed are uniformity of touch combined with ease and rapidity. In other typewriters a motor is used to shift and return the carriage. Noiseless typewriters have proved a welcome innovation.

Though there are numberless differences in detail, it is seen the great majority of typewriters fall into two general classes: type-bar machines, in which the types are carried on the end of levers or type-bars which strike the paper at a common printing point when the keys are depressed; and type-wheel machines, in which the types are arranged around the circumference of a wheel, or segment, which is rotated by the action of keys until corresponding type is brought around to the printing point. The type-bar machines are by far the most common.



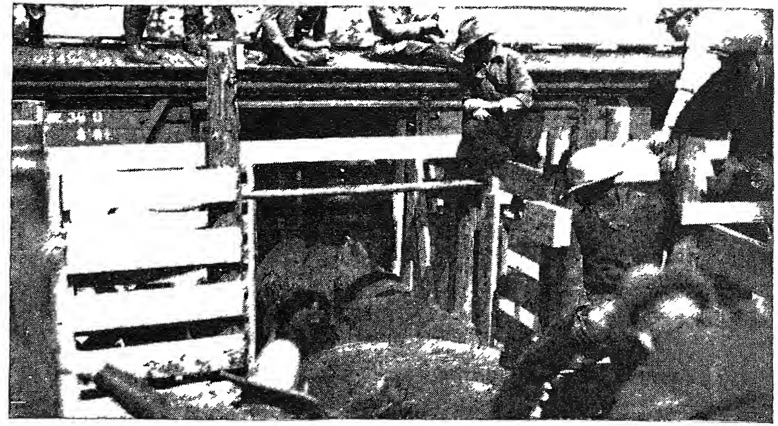
TYPEWRITER AND ADDING MACHINE ARE COMBINED IN THIS ELLIOTT-FISHER ACCOUNTING MACHINE

No typewriter can do satisfactory work unless all characters come precisely to the same printing point. To secure this result, the mechanical problem of confining in an extremely restricted space a strong, rigid and light system of levers, supported on bearings steady and adjustable for wear, has given wide scope to the ingenuity of inventors.

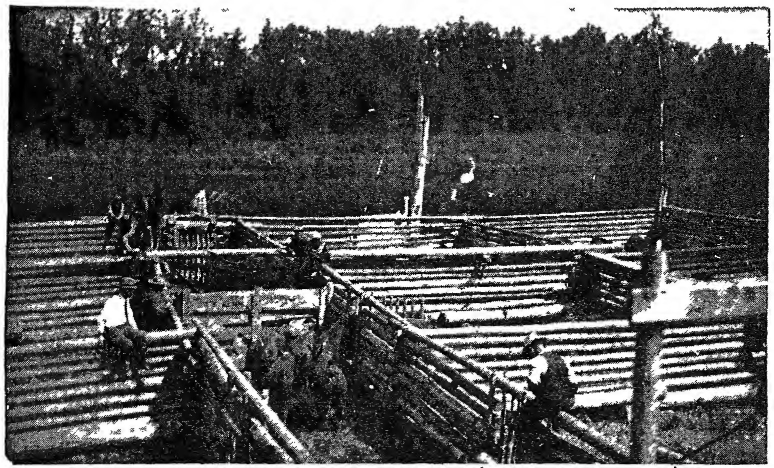
Speed and ease of operation are furthered by many ingenious devices. In some machines margins are adjusted automatically by a special margin-setting mechanism. A touch-control system adjusts the tension of the mechanism that raises the type to the paper; the operator can adjust this mechanism to suit his own style of typing. Electric typewriters have been developed; in these a very slight touch actuates the key bar. The letters produced are uniform, as in printing, since they are not affected by the lightness or heaviness of the operator's touch. A device called a justifier is used on some typewriters; with this the operator can make the right-hand margins as even as the left-hand ones.

Typewriters have been developed for all kinds of special requirements. Some machines produce the raised letters of the Braille alphabet, for the use of the blind. Others write in extremely large type, which will not tax the eyesight of people with faulty vision. Still others are provided with special symbols, like those used in mathematics. Special typewriters have been developed for the different languages. A simple type substitution makes it possible to provide accents for languages like Spanish and French. In some cases the mechanism is adjusted so that the typewriter will move from right to left; this is necessary in writing languages like Hebrew.

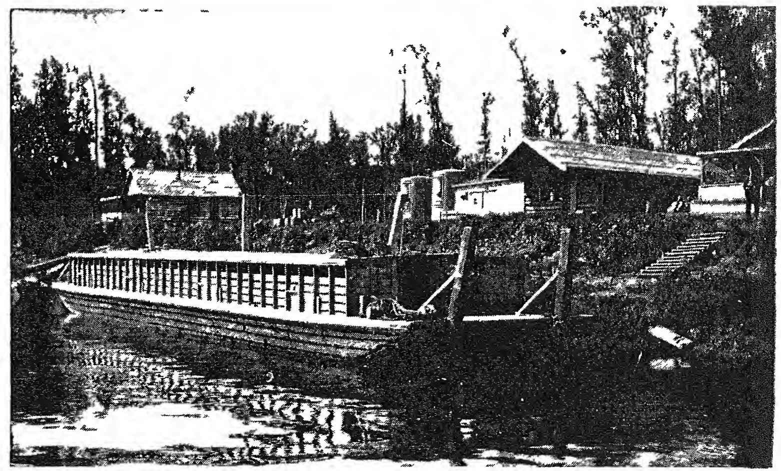
ROUNDING UP THE BUFFALO INTO LOADING CORRALS



LOADING THEM INTO FREIGHT CARS FOR SHIPMENT



UNLOADING INTO CORRALS AT RAIL END (WATERWAYS, ALTA)



THE SCOW BUILT FOR THE LAST STAGE OF THEIR JOURNEY

Shipping bison, to make room for the natural increase of the herd, from the Wainwright National Park to Wood Bison range in North West Territories

Photos Canadian Natural Resources Intelligence Service

DISAPPEARANCE OF OUR WILD LIFE AND THE RISE OF CONSERVATION

GAME AND BIRD SANCTUARIES

WHEN the white man first set foot on the shores of America, he found a country teeming with numerous forms of wild life. Birds, fish and game mammals were so lavishly plentiful that the like has never been seen anywhere else in the world.

The passenger pigeon, during the migration periods, and while wandering in search of food, occurred in vast flocks numbering millions of individuals; great masses of birds that actually obscured the sun, were days in passing a given spot. As late as the year 1866, a flock was seen in Canada which obscured the sun for fourteen hours, and was believed to have averaged three hundred miles in length and a mile in width. Audubon estimated the number of pigeons in a flock that had passed overhead, allowing two pigeons to the square yard, as 1,115,136,000. The present generation can not comprehend the vast spectacle afforded by these great flights of the passenger pigeon, but there are many persons still living who saw them, and who, in a measure, aided in the extinction of the species.

Vast areas of the United States and Canada rumbled to the tread of the American bison or buffalo. This animal, without a doubt the most noble of its family, and the largest of the animals found upon our continent, actually occurred in countless millions. Its history is worse than tragic. Just a few years ago it was on the very verge of extinction, and was saved only through the timely action of the American and Canadian Governments.

The great auk, a flightless bird about the size of a goose, and related to the murres, was formerly abundant in the region of the Gulf of St. Lawrence and as far south as the New England States. All through the latter part of the seventeenth century, the auks were killed in thousands by the crews of sailing vessels for the sake of the oil they contained, and fishermen salted them down by the ton. Owing to the fact that the breeding grounds were restricted to a few islands, and the birds without the power of flight, they were easily captured. The end was inevitable. The species is extinct. The final destruction was so unexpected and so complete, that today there are only about eighty mounted specimens and about seventy eggs in the museums of the entire world. The eggs are worth about $1,200 each.

The American or prong-horned antelope is not a true antelope but is the sole member of a unique family found only in North America. It is the most graceful of our hoofed animals. Like the members of the deer tribe, who shed their antlers every year, it sheds its horns, but the outer sheath only. The new horn grows from the persisting inner core. As in the cattle tribe, the horns are hollow. It has several characteristics found in no other ruminant: it is the only mammal with hollow horns which bear prongs; the horns are placed directly above the eyes; it has no dewclaws; it has erectile hair on the rump; and the hair on the body and neck is tubular. The possession of these peculiar characteristics renders the pronghorn unique and worthy of our best efforts towards its preservation. And yet, in spite of its great numbers, the desire to kill was so prevalent that the dawn of the twentieth century found the former great herds reduced to a few thousands.

Works made by man may be destroyed, but they can be builded anew and better than before. When a species disappears, it has gone forever. Nothing that man can do will bring it back Therein lies the reason why we should devote our best efforts to the preservation of our wild life for the generations to come. Our wild life is a heritage, for us to keep and cherish for our children.

The disappearance of our animals has been caused mainly by wanton destruction. In the days of the Indian, before the colonization of the country, and the subsequent almost universal use of firearms, our game suffered no apparent diminution in numbers. He seldom killed more than could be used for food, and as the total Indian population was not very great, the effect upon the game supply was negligible. With the coming of the white man, conditions rapidly changed. A market for furs immediately came into existence. They became a medium of exchange, and Indian and white man began an extensive trade in the handling of pelts. Large cities sprang up along the Atlantic seaboard, and the adventurous pioneer penetrated farther and farther into the unknown wilderness, down the Ohio, across the Mississippi, and finally to all of the western regions of the country. The exploitation of our natural resources had begun.

Early inhabitants of the country believed that the supply of game was inexhaustible, and the kill was always greater than need demanded. It is difficult for us today to condone that indiscriminate and wanton slaughter. But, undoubtedly, reason was beclouded by the vastness of the supply at hand. With a flock of two billion passenger pigeons going overhead, we must try to forgive our forefathers if they killed more than they could use, for we ourselves are far from being without guilt in our own day. It was inevitable that certain forms of our wild life should be greatly reduced in numbers, because of the gradual deforestation of the country and the rise of agriculture. But this alone can not explain the disappearance of the passenger pigeon, the great auk and the Labrador duck.

Thousands of great nets, guns, sulphur pots, and other devices were used by market hunters in capturing the passenger pigeon for the market. The pigeons were harried continually while on their migratory flights. The majority of the young were killed and shipped to the market by the train-load. Persecution followed them wherever they went; it was inevitable that they must disappear from the earth.

In the case of the great auk, the cause of its extinction was also ruthless slaughter. Nesting in great numbers in a few restricted localities, and being rather unsuspicious, the killing of enormous numbers of them was an easy matter. Killing the young birds prevented any natural increase. The end was sure and swift.

The Extermination of the Bison

The causes of the virtual extermination of the bison or buffalo were mostly unavoidable. However, it remains to the everlasting shame of the American people, that they, in such a ruthless manner that it has been without parallel in the world, practically exterminated one of the most inoffensive and noble animals of the earth.

According to Hornaday, in "The Extermination of the American Bison", its range was as follows: "Starting almost at tide-water on the Atlantic coast, it extended westward through a vast tract of dense forest, across the Alleghany Mountain system to the prairies along the Mississippi, and southward to the delta of that great stream. Although the great plains country of the west was the natural home of the species, where it flourished most abundantly, it also wandered south across Texas to the burning plains of northeastern Mexico, westward across the Rocky Mountains into New Mexico, Utah, and Idaho, and northward across a vast treeless waste to the bleak and inhospitable shores of Great Slave Lake itself."

Today, in all of the above region, the bison is practically unknown. There are no wild bison within the boundaries of the United States, and the only really wild herd is found in Canada, south of Great Slave Lake. This herd has long been segregated from the other American bison,

Photo Bureau of Biological Survey, U. S Dept of Agriculture

GROUP OF ANTELOPE SAVED BY A FEDERAL GAME REFUGE

and they have formed a distinct sub-species, called the wood bison. A recent action of the Canadian Government in moving plains bison from the south to the area inhabited by the wood bison, may tend to destroy the sub-specificity of the latter, a larger and finer animal.

Early settlers thought the supply of bison to be inexhaustible. Again they were misled by the vastness of their number. The flesh was an important food item to all of the early travelers and explorers. The skin, when tanned, furnished an excellent robe for winter use. Indeed, the presence of the bison was a not unimportant factor contributing towards the early opening up of the country. With the continual settling of new areas and the growth in population, more and more were killed for food, but as the supply was so great, only the choicest parts of the animal were used, the rest being left to the wolves and vultures. Tens of thousands were slaughtered. A market for robes came into existence. The slaughter increased by leaps and bounds, and soon the "buffalo" herds were followed everywhere by the robe hunter. But not only were they killed for food and clothing; thousands of hunters, so-called sportsmen, followed the herds, filled only with the desire to kill, shooting down the defenseless animals, and ceasing only upon becoming tired of the "sport", or when their ammunition gave out. They were killed by still-hunting, sometimes over a hundred animals being shot from one stand They were hunted from horseback, driven over precipices, impounded in improvised corrals, and killed by almost every device that the hunter could think of. Early in the nineteenth century all of the outlying herds had been exterminated, and a few far-seeing persons began to realize that the animal was well on the way towards extinction. In 1832 it was estimated that 2,000,000, or perhaps 3,000,000, were being killed annually. The construction of the Union Pacific Railroad, begun in 1865, marked the breaking up of the original band of bison into two great herds, a northern and a southern. Hunters now found ready access to the "buffalo" country. Enormous slaughter followed, especially during the years from 1871 to 1874. The bison were doomed, and the year 1875 found the range of the southern herd marked only by bleaching bones.

Although its numbers were not so large, the northern herd occupied a larger area than the southern, and it therefore managed to hold out longer against its persecutors. Following the extermination of the southern herd, the work of destruction shifted to the north. The year 1883 found the herd broken up, and only a few wandering bands that had managed to elude the hunters were left to roam the plains. Hornaday, in 1899, estimated that the total number of bison in a wild state was only 635 animals! Thus disappeared the bison in the face of advancing civilization.

Occupying lands that have since furnished a fair share of the world's food supply and homes for millions of people, it was inevitable that this stately but slow-thinking animal should give way before the surging tide.

The American antelope, or pronghorn, like the bison, is an animal of the plains, although it is able to exist under much more arid conditions. The pronghorn ranged over much the same territory as the bison, although the area was not so extensive. When the white man came to America, they were found from the provinces of Manitoba, Alberta and Saskatchewan, in the north, through the central plains to the valley of Mexico in the south,

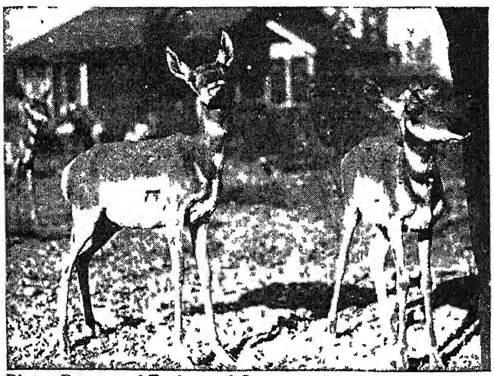


Photo Bureau of Biological Survey

CLOSE-UP VIEW OF ANTELOPE
Buck, doe and kids (the doe as yet without horns)

west to eastern Washington, Oregon and the Pacific coast in California, and east to western Minnesota and Texas. Thus, unlike the bison, the pronghorn never ranged east of the Mississippi, and its southern range extended farther into the hot plains of central Mexico. Old accounts agree that it exceeded the bison in abundance, and it has been estimated that its former number was not less than thirty or forty millions.

Today, the pronghorn is extinct over a large part of its former range, although, due to its extreme shyness and swiftness of foot, it has been able to persist over an unbelievably large area. It suffered the same persecution as the bison, but it has managed to hold on where the larger and more stupid animal has long since disappeared. The settling of the open country and the resulting curtailment of its range, and the rifle of the hunter, have had their effect. Where the animal formerly numbered in the millions, it was estimated in 1924 by E. W. Nelson, Chief of the United States Bureau of Biological Survey, that the total number then living in North America was only 30,326.

A great part of the country that was formerly occupied by the pronghorn has since become extremely valuable farming land. So, as with the bison, it was inevitable that it should give way to agriculture over a large part of its range. But the pity remains that the animals were killed in such enormous numbers, satisfying only the lust to kill, and with utter disregard for the future

The Beginnings of Conservation

Early in colonial times it was seen that certain forms of our animal life could not hold their own against the ever increasing toll taken by man, and laws were passed which aimed to conserve the supply of game for the future. The conservation idea thus early came into being. It was painfully slow in taking root. Practically all of our animals were so plentiful that most people could not see the need for conservation. Others believed that the game belonged to the people and was theirs for the taking. It was necessary that our people be subjected to an educational process and learn by bitter experience that our wild life is a valuable asset and must be protected if it is to remain for the future.

The great auk disappeared entirely before anything could be done in its behalf. The Labrador duck, through reasons that are unknown, suffered a like fate. The passenger pigeon and the Carolina parrakeet linger only in memory. We have discussed the bison and the pronghorn, and today, still other birds and mammals demand our protection if they are to be preserved.

In an effort to save the bison, the United States and Canadian Governments took rather belated action in establishing "buffalo parks" wherein the animals were

absolutely protected The American Bison Society was formed, and this and other organizations did valiant work toward saving the bison. Under the protection now offered them, the small herds increased slowly but surely The animals in several parks did exceptionally well. The herd at Wainwright, Alberta, with a nucleus of 709 head, increased in ten years to over 5,000. The frontispiece of this chapter shows the manner of disposing of this increase. The bison in the parks of the United States increased in a similar manner. They were saved from total annihilation in the very nick of time.

Several efforts have been made to domesticate the bison or to cross it with various breeds of domestic cattle. So far, these efforts seem to have been rewarded with indifferent success But, undoubtedly, the bison should be a valuable addition to the list of our domestic animals. Not only does it have great beef-producing possibilities, but it also produces a robe, the value of which, it will be remembered, almost led to the extinction of its bearer.

About nine-tenths of all the pronghorned antelopes alive today are found within the boundaries of the United States, and it has already been mentioned how remarkable it is that they have been able to cling so tenaciously to the areas formerly inhabited by them. Yet their numbers have been so reduced and the sentiment of the people living in the sections where they persist seems to be so little in their favor, that these graceful little animals are in danger of extinction. Much has been done by the United States Government, through the Biological Survey, towards saving these animals. Many efforts have been made to raise them in parks, but with little success. Experiments have shown that they may be raised on large fenced areas, and on open areas where they can be protected from their enemies. It is very likely that the species can be perpetuated and that the disposal of the increase will be a matter of game administration. Several antelope refuges have been established and it is hoped that methods of care and management will be developed.

One interesting little band of antelopes has been established about 3100 feet below the south rim of the Grand Canyon, at the foot of Hermit Trail. Here, on a half-mile wide shelf where there is plenty of water, practically no enemies, and where escape is impossible, twelve antelopes were placed in 1924. Six fawns were born in the spring of 1927, three of which survived. This little group of pronghorns has become exceedingly tame and has been much photographed by tourists, at times, it is said, with a considerable amount of difficulty and loss of patience, because they will not keep far enough away. "One morning a man trying to photograph one with a reflex camera was considerably put out because a doe insisted on licking his lens."

Another reservation designed to aid in the preservation of the antelope has just been made in northern Nevada, on the Last Chance Ranch, a range of 380 acres. This ranch has been taken over by the National Association of Audubon Societies, in the hope that they will be able to save the herd of antelope still found in that region. The country round about is mostly desert The ranch contains open water, and in the spring antelopes come from great distances to have their fawns on the slopes surrounding the water hole This is the first Audubon Society reservation or sanctuary for the preservation of mammals, and the success of the venture will be watched with interest.

Now, as to the Birds

When America was first settled the colonists found new species of birds and mammals. In most cases these were named for familiar and more or less similarly colored birds in the mother country. Thus the American robin was named for the robin of northern Europe. Sentiment in connection with the birds was, however, usually not transplanted to the new country. As a result, practically all of our birds were killed indiscriminately and used for food, even though they might be good songsters, insect eaters or weed destroyers. Gradually, however, sentiment grew in favor of our feathered friends. Farmers began to notice that certain birds,

such as our native sparrows, fed upon weed seeds, or noxious insects, or both. Other birds, in building their nests around our homes and gardens, and through their cheery voices, began to work their way into the hearts of the people But due to the rise of agriculture and to the destruction of our wild life by the ever increasing population, certain species, including our game birds, became noticeably fewer in numbers. Gradually, laws were passed designed to help those species that could not seem to hold their own. As the years passed our modern system of game protection came into existence, and although it is by no means perfect, it has done wonders towards conserving our wild life

Wild game killed in the open season was formerly sold in all of the markets of the country. This pernicious practice was the principal factor contributing towards the extermination of the passenger pigeon. Other game suffered likewise. A great step forward was taken in 1911, when the State of New York passed a law prohibiting the sale of any American wild game anywhere in the state. This does not prevent the sale of birds and mammals raised in captivity. Other states followed with similar action, and the number of game birds, especially, that were killed every year, was cut to about half of those killed in the days of market hunting, previous to the enactment of the law.

Another, and one of the greatest steps upward in the history of bird conservation, occurred in 1913, when, after a long and bitter struggle, a clause was placed in the tariff bill which absolutely prohibited the importation of "any fancy feathers, plumes, skins, or quills of wild birds, other than ostriches and domestic fowls, for domestic purposes." The amount of good that this measure has done for the birds of the world is incalculable. The feather trade had accounted for the death of millions of birds yearly. According to Hornaday, over a hundred species of the birds of the world were affected by this measure, many of them having had no protection at all, in so far as the laws of their own country were concerned.

The Federal Migratory Bird Law

Long years of educational efforts and work on bird conservation was rewarded in 1913 by the passage of the Weeks-McLean bill, afterwards known as the Federal Migratory Bird Law. Previous to the enactment of this measure it was impossible to achieve the best results and necessary co-operation, because of divided authority and a lack of unity of purpose among the different states, in regard to conservation measures Migratory birds were decreasing steadily despite the laws for their protection. It has already been mentioned how the passenger pigeon and the Labrador duck became extinct. Another migratory bird, the Eskimo curlew, which also occurred in enormous numbers, has recently become extinct, due principally to the market hunter. The wood duck, the most beautiful of our wild ducks, became so reduced in numbers that if it were to be preserved, immediate and additional protection became necessary. Of course some of the steady decrease, especially in the case of ducks, geese, and shore-birds, was due to unavoidable causes, such as the settling of the land comprising their breeding grounds, but much of it was due to the lack of proper legal protection.

In the United States some of the states had good laws and they were strictly enforced. Others had few laws and failed to enforce those they had. Spring shooting was not generally prohibited, and many mated birds were killed on the northward journey to their breeding grounds. The efforts of many sportsmen, game protective associations and others, to remove these conditions, finally culminated in the Federal Migratory Bird Law, which secured many far-reaching benefits. The length of the open seasons was generally reduced and the seasons were made more uniform. Spring shooting was entirely prohibited. A closed season was placed upon certain birds, particularly shore-birds, and the shooting of insectivorous birds was entirely prohibited. The almost immediate result of this measure was a marked increase in the numbers of migratory wild fowl.

Photo Dr Frank M Chapman, American Museum of Natural History

PELICAN ISLAND, THE FIRST FEDERAL BIRD REFUGE

Birds in their migrations are no respecters of man-made international boundaries Thus the success of any measures made in Canada, to protect her breeding colonies or to augment the supply of her migratory birds, was dependent upon the reception the migrants received during the migration flights and winter residence in the States. It was realized that the fullest benefits from bird conservation could be derived only from international coöperation between the United States and Canada Several conferences between the representatives of the two Governments followed, and a treaty, incorporating many of the features of the migratory bird law, was finally signed by the two Governments in 1916 and became a law. Thus evolved the greatest bird protective measure in the world, called the Migratory Birds Convention Act. Over one thousand species of birds have been affected by its provisions, and benefits therefrom accruing to both of the signatories are becoming more and more evident as time goes on.

Game reservations and sanctuaries have helped immensely towards conserving our supply of wild birds and mammals. Most of the reservations that have been established are National Bird Refuges. Their chief aim is to protect breeding colonies of water-birds or to give refuge to migratory wild fowl during their seasonal flights, or during the winter. Other bird refuges have been established and are being maintained by the National Association of Audubon Societies. Another organization responsible for a number of bird and game sanctuaries is the Federation of New England Bird Clubs. It should also be noted that there are many sanctuaries owned and maintained by private individuals. The first, and now perhaps the most famous, national bird refuge, was established on Pelican Island, in Florida. That good conservationist, Theodore Roosevelt, during his term of office as President of the United States, helped to establish, or made by executive order, three national bison herds, four national game preserves, and fifty-three bird refuges. Since that time the number of wildlife refuges has increased to more than two hundred and thirty.

The Dominion of Canada also has an extensive system of game refuges and preserves. Since the adoption of the Migratory Birds Convention Act, many bird sanctuaries have been established, ranging across the continent. We have already mentioned the herd of bison at Wainwright, Alberta, and the wood bison south of Great Slave Lake. There is a thriving herd of about 300 prong-horned antelopes at Nemiskam, Alberta. Recently a dozen or more islands in the Gulf of St. Lawrence were made bird preserves. All of these islands are the breeding places of numerous sea-birds. In the past they suffered greatly from the depredations of eggers and fishermen, and the remnants of former great colonies were in sore need of the protection now offered them. Some of these reservations, such as Percé Rock and Bonaventure Island along the Gaspé coast of Quebec, are each year visited by an increasing throng of tourists. Here, on Bonaventure Island, is found the only large colony of breeding gannets, and the only accessible one, along the shores of North America. The locality is also one of the most beautiful and picturesque spots on the continent.

In the United States, state game preserves are also gradually being established. It is generally agreed that Pennsylvania has the best system. Through the mountainous and generally forested part of Pennsylvania, the state has acquired over a million acres of land. Some of this is abandoned farm land, and practically all is of no agricultural value. At suitable localities certain desirable tracts have been marked out by being enclosed with a single strand of heavy wire. The area within it is thus designated as a sanctuary, and absolutely no hunting or killing of game is allowed within its boundaries. The thousands of acres of land surrounding these areas are free and open to the hunter.

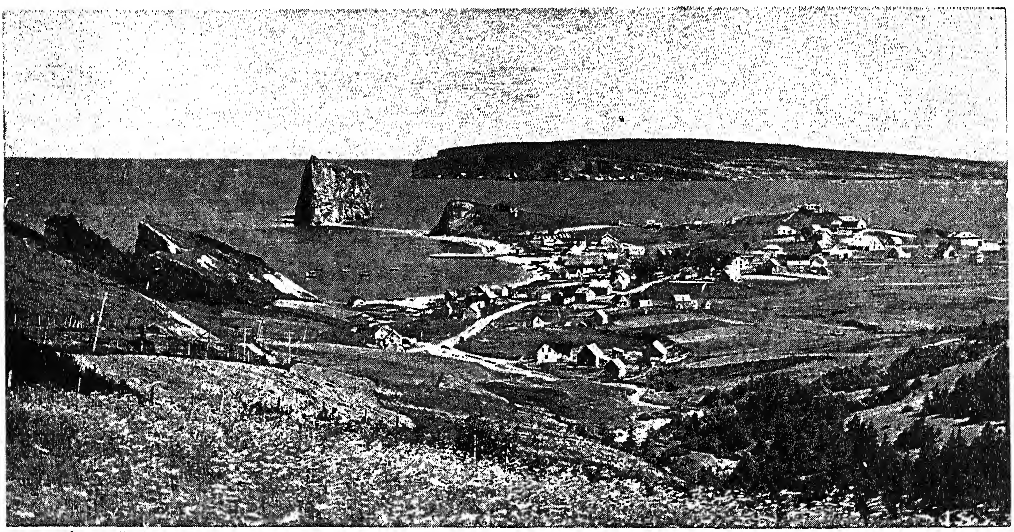


Photo C. W. Leister

TWO CANADIAN BIRD RESERVATIONS IN THE GULF OF ST. LAWRENCE

Percé Rock and Bonaventure Island. One of the beauty spots of North America.

The state game commission has stocked the preserves with deer and other kinds of game. Intelligent laws protecting birds and game have been passed and are rigidly enforced. The commission has labored in various ways to increase the supply of wild animals throughout the state, and their efforts have borne fruit. Twenty years ago there was but little game in the state. It was said to be "shot out." At the present time, it is believed by many that Pennsylvania has the best supply of game of any state in the Union.

A great step forward in the growth of the conservation idea has been marked by the establishing of a system of national

parks, both in the United States and in Canada. The United States now has twenty-six, the first (1832) being at Hot Springs, Arkansas. Shenandoah National Park was created in 1935, and embraces some 262 square miles in the outstanding scenic section of the Blue Ridge Mountains. The Canadian National Parks have an area of some 12,000 square miles, and, as in the United States, most of them are situated in the mountain region of the west. The greatest and best known is Jasper National Park, in the Northern Rockies, which includes about 4,400 square miles.

The National Parks offer a living museum of all that is best in nature, "mountain scenic masterpieces", forests, lakes and streams, all are blended in such a majestic manner that the visitor needs must stand enthralled upon beholding them. Each and every park is a bird and game preserve, and here live the animals undisturbed, as did their ancestors before the coming of man. Since no hunting or shooting is allowed many of them have lost their acquired fear of man and have become exceedingly tame and confiding.

The most important park in the country, from our standpoint, is the Yellowstone National Park, in Wyoming. Until Jasper Park was formed, it was the largest bird and game preserve in the world. Now that honor goes to its Canadian neighbor. All of the wild animals that naturally occur in the region are found in abundance, living their natural lives throughout the 3,348 square miles of mountainous and varied areas of the park. Of the hoofed animals, the mule or black-tail deer, bison and moose, are found in goodly numbers. Here lives the largest single band of antelope in the country. Of the wapiti, or elk, there are over 40,000 head. Here also are found the mountain lion, sometimes called cougar or panther, the wolf, the coyote, and the fox.

The wapiti has presented a real problem in conservation. Formerly it was found over practically the same territory as the bison, approximately one-third of the mainland of North America, and in numbers estimated at 10,000,000 head. Today not a single elk remains alive in a wild state in the eastern part of the continent, and they are making their last stand against their great enemy, man, in the Rocky Mountain region of the west. More than four-fifths of our remaining elk are found in Yellowstone Park and vicinity.

During the summer excellent grazing is found on the high mountain meadows of the park and of the mountains to the south, but with the coming of the deep snows of winter the elk are forced down to the lower valleys, where the snowfall is not so heavy and where they can still find food.

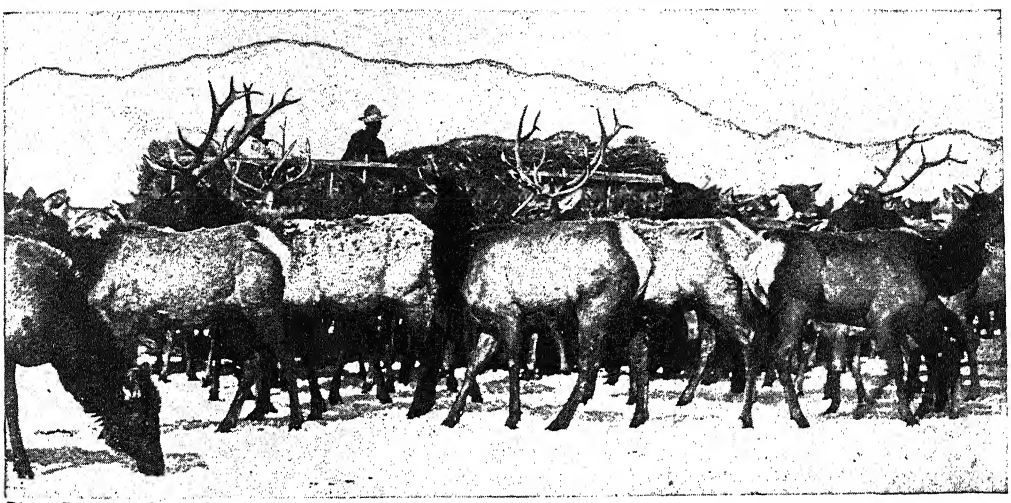


Photo Bureau of Biological Survey

ELK BEING FED HAY IN JACKSON HOLE, WYOMING, TO PREVENT STARVATION

Food Relief in Severe Winters

Part of these elk, known as the Jackson Hole herd, have received considerable attention the last few years because of the large numbers that have starved owing to the failure of the winter food supply. Food is plentiful in the summer range along the southern border of Yellowstone Park, the mountains to the south, and in the Teton State Game Reserve. All of this range has been unaffected by settlement and conditions are ideal for the welfare of the elk. But ranchers and stockmen have settled in the valleys comprising the winter range, and much of the territory is now fenced. In past winters it is said that certain ranchers had to guard their stock of hay and stand off the starving elk in order to save their cattle from a similar fate.

Thus the settling of the valleys, and the cutting off of the elk from their winter grazing lands, has caused the seasonal ranges to become disproportionate in food supply. Each winter, with the natural increase of the herd, the food supply becomes more and more inadequate. Finally, along comes a severe winter, there is not enough food for the augmented herd, and starvation for thousands of them is the result. In an effort to avert this, and to offset the winter scarcity of food, feeding has been resorted to, and since 1912 over 10,000 tons of hay have been fed to the Jackson Hole elk. But this winter feeding does not lead to a solution of the problem; it only means that more elk are saved to feed the following winter. Some way must be found to dispose of the natural increase of the herd. In past years a number of animals have been captured and shipped to other sections, where they have been used to stock vacant ranges, but not enough of this has been done to take care of all of the surplus.

Recently, a committee, appointed to examine the elk situation, has recommended that an effort be made to keep the Jackson Hole herd at about 20,000 head; that certain additional lands adjoining the winter range be purchased by the Government; and that further investigation be made concerning the management of the herd under present conditions, including a satisfactory method of disposing of the increase.

The bears of the Yellowstone, both grizzly and black, have become famous. Being absolutely protected over a period of years, many of them have become exceedingly tame and some have formed the habit of coming to the camps regularly to beg for food. At times, when the expected handout is not forthcoming, they take matters into their own hands, as it were, and help themselves. The edible supplies of many a camp have become bear-food during the absence of the rightful owner. Certain individual bears have become so bold as to be a menace to the public safety and it has been found necessary to deal with them summarily. In several instances, unwise action on the part of campers has found the bears to be charged with potential disaster.

Bears and Rocky Mountain Goats

Another great outdoor laboratory for the study of animal life is Glacier National Park, in northwestern Montana, the "wildest" of our national parks. Here is found perhaps the best locality in America to observe the Rocky Mountain goat, for these animals are common on the high peaks and ridges, and the sturdy climber can follow their trails along the shelves and ledges and study them in their own domain Unfortunately they keep to the higher altitudes and only the more venturesome of the tourists ever see them. It is believed that they would frequent the lower trails were it not for the fact that the coyotes prey upon the kids.

Our states have shared the work of the federal government in bringing their citizens in contact with the out of doors, by the establishing of state parks. Thus forty-three states have established either state parks or forests for the recreation of their people, and have begun to realize the great educational possibilities that lie in the state park idea. As in the case of our national parks, the state park aims to preserve some outstanding work of nature or a locality possessing great historical interest.

Several of the national parks have established a Nature Guide Service and have a Park Naturalist who assists visitors in their study of the natural history of the park. Many of the state parks have developed a service with somewhat the same idea in view. In many cases, educational institutions have coöperated in the work, making use of the facilities of the park. The number of persons taking part in the field trips, excursions and nature study courses, is an ever-increasing one. Grown-ups and thousands of children

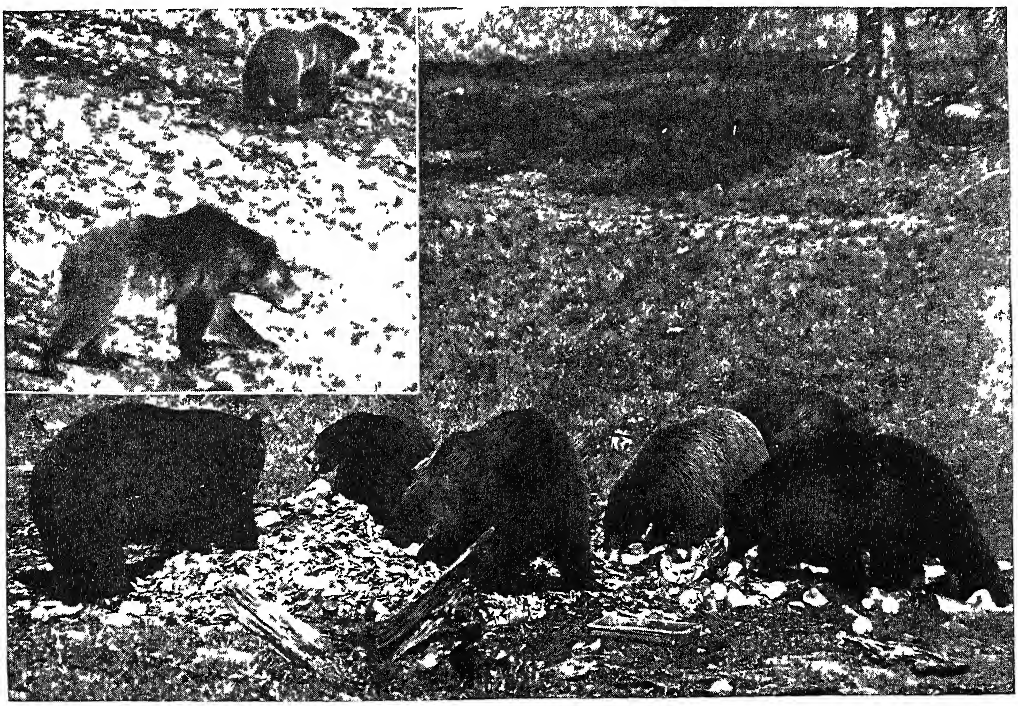


Photo Bureau of Biological Survey

GRIZZLY AND BLACK BEARS IN YELLOWSTONE NATIONAL PARK

are reached by this nature study service, to their great enjoyment, and they are taught, at first hand, the principles and meaning of conservation.

There has been an increasing disinclination on the part of farmers and landowners to allow the general public to hunt on their property, and the amount of "open land" has decreased considerably. Indeed, it has become apparent that, in the not so far distant future, there will be very little hunting allowed on privately owned land. Throughout the country there are numerous localities with considerable non-agricultural land, best fitted by nature for the production of forests and game. It has been suggested that such lands be acquired by the state, stocked with suitable game, and either used as sanctuaries or opened as "public shooting grounds" Individual states have shown considerable interest in this proposition and have authorized commissions to investigate and recommend tracts of land suitable for the purpose. Canada has already established fifty-one areas as public shooting grounds.

We have now briefly traced the history of certain forms of our animal life and the gradual rise of the conservation idea. Still other species of our birds and mammals are sure to become exterminated in the future. But a change in attitude towards our wild life has gradually been brought about. Most of us now deplore the excessive killing of any of the wild creatures of the continent. It has usually been necessary to point towards the economic value of a species in order to gain consideration. Now, more and more people are beginning

to see value in the thing itself A recent writer has expressed this as follows: "A wild duck, brought to the table, may be very tasty, but a wild duck in flight over a moor, or swimming on the surface of a wilderness pond, is a thing of beauty, worth saving for its own sake."

Bird Banding

Another recent advance in our knowledge of wild life has been brought about through the practice of bird banding. Audubon, about the year 1803, at his home on the banks of the Perkiomen Creek, in Montgomery County, Pennsylvania, placed some little silver wire bands on the legs of a brood of young phoebes that had been reared in his back yard. He was delighted to find that two of the banded birds returned to the same locality the following year. This incident very likely marked the beginning of bird banding in America. However, very little more was accomplished until about a hundred years later, when a revival of the practice began to show marvelous results, especially so during the last ten years.

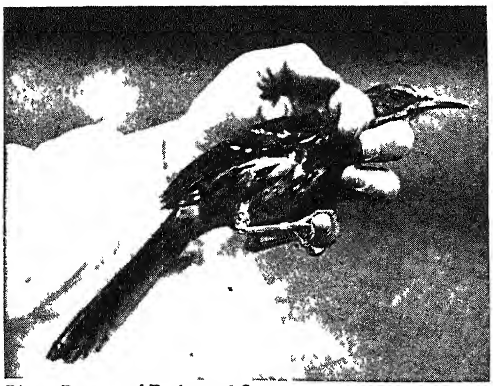


Photo Bureau of Biological Survey
BANDING A BROWN THRASHER

It had long been suspected that individual birds return to the same locality year after year to nest, but it took bird banding to really prove that fact. We are also learning something concerning the migration routes that different birds follow, how fast they travel, how long they remain in certain localities, and the total length of their migration journey. Other facts, equally important, are gradually being brought to light.

Bird banding has now been systematized under the direction of the United States Bureau of Biological Survey, at Washington. Results can readily be ascertained through examination of the records that are centralized there. The kind and style of the bands that are used has been standardized, and all are issued by the Survey. They are of aluminum, with the letters "BIOL. SURV." and the number of the band on one side, and the letters "WASH., D. C." on the other. Tens of thousands of birds have been banded, and a large percentage of "returns" made.

Several birds banded in America have been recovered in foreign countries. A common tern, banded in 1913, on Muscongus Bay, in Maine, was picked up dead, four years later, by a negro, on a branch of the Niger River, in Africa. An Arctic tern, banded at Red Islands, Turnevick, Labrador, on July 22, 1927, was found at La Rochelle, France, on October 1 of the same year.

Doubtless many more equally interesting records concerning the travels of our birds will come to light as the practice of banding is carried on. Much work remains to be done. No harm at all is done to the birds, and it is hoped that many more persons will assist in this fascinating branch of ornithology.

Photo Bureau of Biological Survey ANTELOPE, WICHITA, OKLAHOMA

The Twentieth Century (1895-) VI

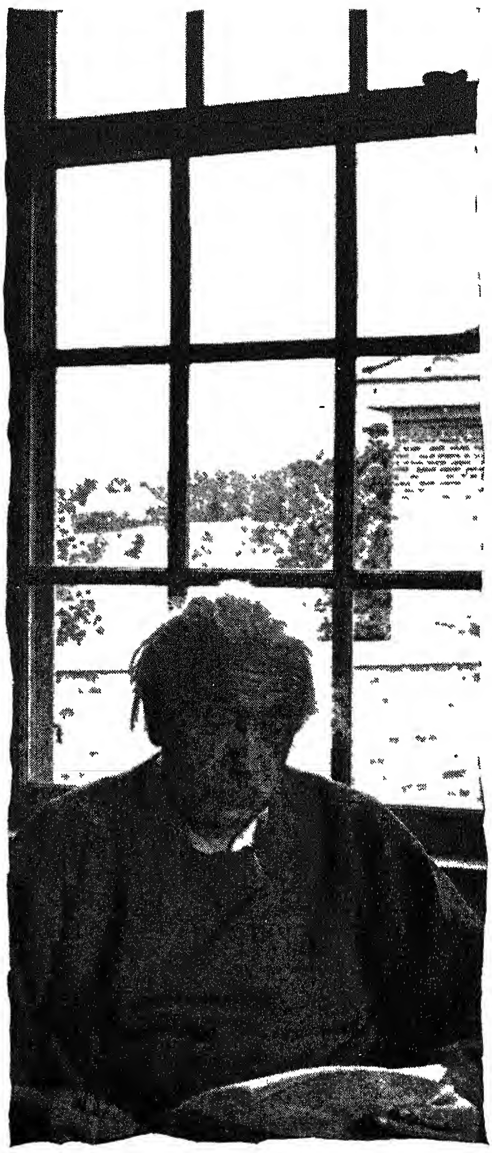
by JUSTUS SCHIFFERES

FROM RELATIVITY TO UNCERTAINTY

THE tone of science in the nineteenth century was positive and materialistic; scientists had cast off practically all ties with speculative philosophy. But today the situation has changed drastically. The modern scientist does not speak with finality; he does not expect to uncover immutable laws. He puts forward his conclusions as relative, tentative and uncertain. Furthermore, certain startling twentieth-century developments in the field of higher physics have brought about a new alliance between science and philosophy. Modern physicists have to deal with unseen — and perhaps forever invisible — worlds within the atom. To solve their problems, they often have to call upon the methods of philosophical inquiry. Many a great physicist today is more nearly a philosopher than he is a technician.

The greatest name in the history of modern higher physics is that of Albert Einstein. With his revolutionary theory of relativity he undermined the authority of classical physics — the so-called laws of motion and gravitation that had been developed by Galileo and Newton and unquestioningly accepted as final for nearly three centuries. Einstein showed that some of the basic assumptions of Galileo and Newton were not justified and that it was necessary to examine anew the problems that they had apparently solved once and for all.

The vital importance of Einstein's work has been universally acknowledged. The Irish sage George Bernard Shaw pro-



Albert Einstein, whose relativity theory changed the course of higher physics.
Alfred Eisenstaedt — PIX

claimed that the great physicist "made a new universe." "Through Einstein's theories, physics is permanently changed," asserted Percy W. Bridgman, Nobel Prize winner and Hollis Professor of Mathematics and Natural Philosophy at Harvard University.

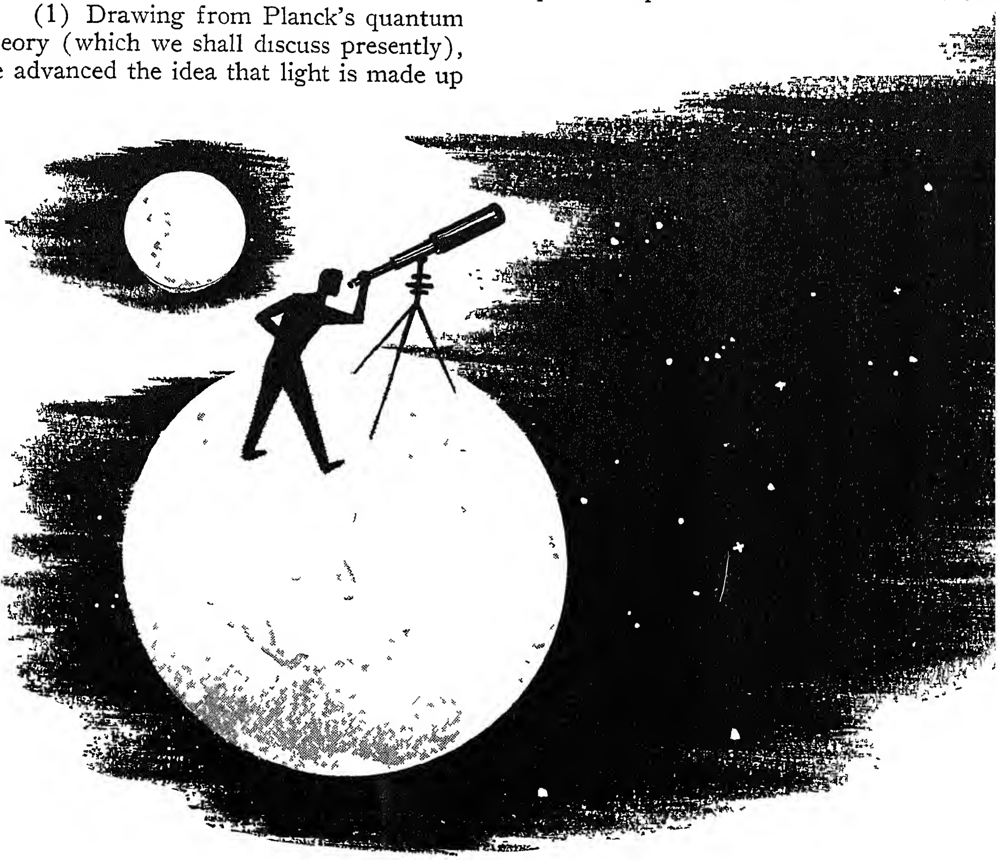
Albert Einstein was born in Ulm, Germany, in 1879 and went to school in Munich. From 1896 to 1900 he studied at the Polytechnical School in Zurich, Switzerland. During the next five years he wrestled with mathematical and physical problems, while he supported his family as a patent examiner.

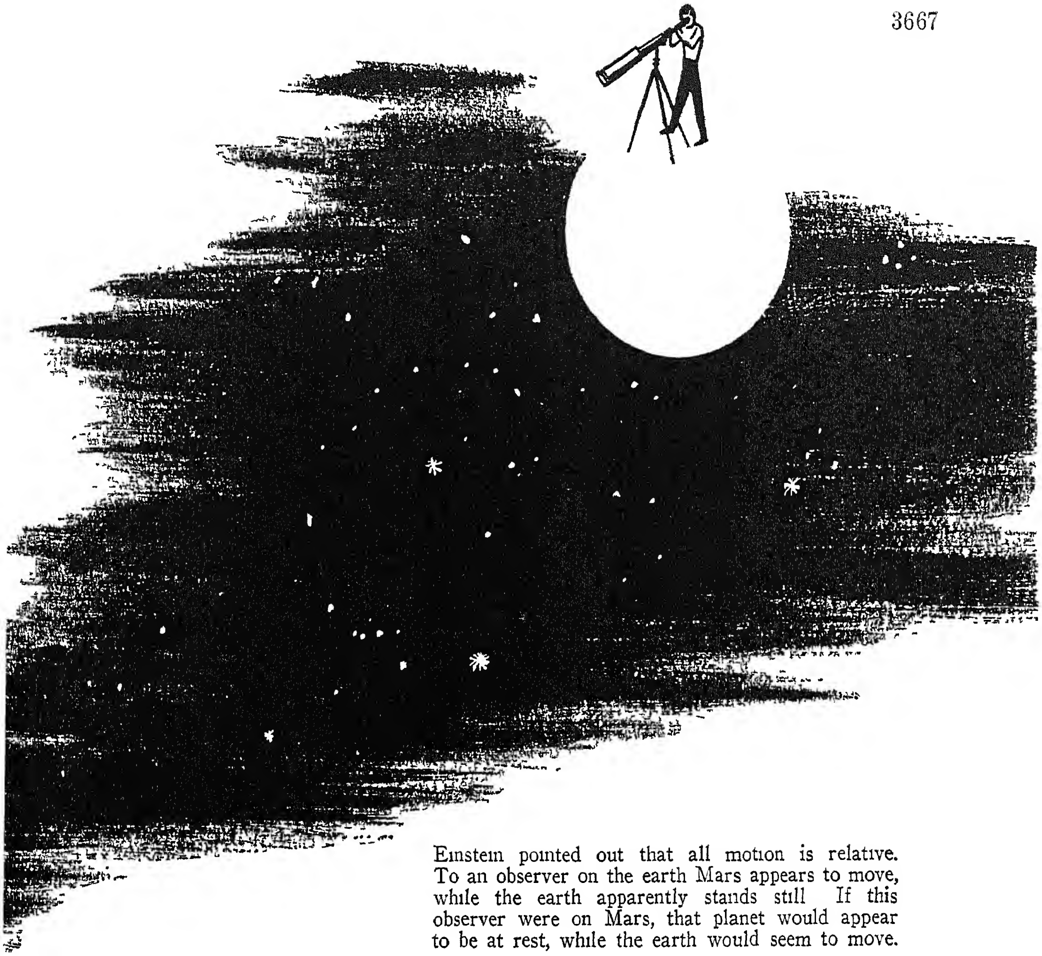
In the year 1905, Einstein made a number of supremely important contributions to scientific knowledge. He published papers on (1) The Quantum Law of the Emission and Absorption of Light, (2) The Inertia of Energy and (3) A Special Theory of Relativity. In these papers he presented the following ideas:

(1) Drawing from Planck's quantum theory (which we shall discuss presently), he advanced the idea that light is made up of photons — that is, bundles, or particles, of energy. Newton had also thought of light as consisting of particles ("corpuscles"); but this concept had been more or less discredited in the nineteenth century. Einstein's photon theory of light led to the development of the photoelectric cell, which opens doors, counts packages and does hundreds of other useful things.

(2) Matter and energy are different phases of the same phenomenon; one can be converted into the other. To show what happens when this transformation takes place, Einstein wrote what has been called the world's most important equation: $E = mc^2$. In this mass-energy equation, E represents energy, m mass and c the speed of light. The harnessing of atomic energy depends upon this concept.

(3) It is impossible to detect any absolute motion in the universe, for all motion is relative; it depends upon the position of the observer. Einstein gave a simple example to illustrate this idea of





Einstein pointed out that all motion is relative. To an observer on the earth Mars appears to move, while the earth apparently stands still If this observer were on Mars, that planet would appear to be at rest, while the earth would seem to move.

relativity. A man riding on a railroad train drops a stone out of the window. To the man on the train, it looks as if the stone follows a straight path as it drops. But to a man standing on the railroad embankment, the path of the stone looks like a curve — a parabola.

Einstein remained in the Swiss patent office until 1909, when he became an extraordinary professor at the University of Zurich. ("Extraordinary" in this case refers to a professor teaching subjects not included in the regular curriculum) In the years that followed, he taught at other universities — at the University of Prague, at the Polytechnical School in Zurich and at the Prussian Academy of Sciences in Berlin. In the meantime he continued his studies, and in 1915 he gave the world his General Theory of Relativity.

This theory is based on the assumption that all motion is relative. To an observer on the earth, say, it appears that our planet is at rest, while the planet Mars is in motion. An observer on Mars, on the contrary, would conclude that the earth moves and that Mars stands still. In this universe of relative and changing values, there is, according to Einstein, one quantity that remains constant: that is, the velocity of light as it passes from one region of the universe to another. This velocity (186,280 miles per second) is an absolute physical constant.

To Einstein, the three dimensions of space — length, breadth and thickness — seemed inadequate to explain the physical universe. For each event in this universe takes place not only at a particular spot in three-dimensional space but also at a definite time. The relationship between space

and time is so important, according to Einstein, that they make up a fourth dimension, which may be called space time. In the four-dimensional universe, what seems to be a straight line leading from one point to another is not really straight at all, but curved. The universe itself is curved, according to the relativity theory.

Einstein worked out a generalized law of gravitation, which differs slightly from that of Newton. In accordance with this new gravitational doctrine, Einstein calculated that a ray of light passing near a large body such as the sun would be bent toward it. This calculation was put to the test in 1919. Two parties of British astronomers proceeded to stations in South Africa and photographed the stars in the vicinity of the sun during a solar eclipse. After a few months the same group of stars was photographed at night when, of course, the sun was in another part of the sky. When the photographic plates were compared, it was found that a ray of light proceeding from a distant star and passing near the sun's surface had been deflected by almost two seconds. (Here, of course, "second" is used in the sense of $\frac{1}{3,600}$ part of a degree.)

Einstein received the Nobel Prize in physics

In 1916, Einstein had been appointed director of the Kaiser Wilhelm Physical Institute in Berlin. Five years later he received the Nobel Prize in physics for his work. His fame was now world-wide; not only physicists but the world at large hailed him as one of the greatest thinkers of all time. In the years that followed, the rise of nazism in Germany made his position insecure. In 1933, therefore, he came to the United States and was appointed a permanent member of the Institute for Advanced Study, at Princeton, New Jersey. In time he became a naturalized American citizen.

As the years passed, Einstein's fame became almost legendary; yet he remained a patient, modest and generous man. He was above all a socially minded person. "From the standpoint of daily life," he wrote in 1931, "there is one thing we know, that man is here for the sake of other men . . . Without the sense of collaborating with like-minded beings in the pursuit of the ever unattainable in art and scientific research, my life would have been empty"

The public at large has taken much too literally the famous saying that "there are only ten men in the world who can understand Einstein." To be sure, the number of those who can understand the mathematical calculations involved in the relativity theory is small. But the average person can grasp the outline of the theory.

The development of non-Euclidean geometry

The mathematical demonstration of the Einstein theory requires a kind of mathematics that is not found in the elementary textbooks. It is called non-Euclidean geometry; it appears at first glance to run counter to the teachings of the ancient mathematician Euclid, whose ELEMENTS OF GEOMETRY has been studied by schoolboys these past two thousand years and more. Actually, non-Euclidean geometry has as much logic and validity as any other kind of consistent mathematical system.

Einstein did not invent non-Euclidean geometry. Mathematicians had begun to suspect as far back as the seventeenth century that Euclid's system did not represent the last word in geometry. They had tried to prove the Euclidean axiom that "through a given point outside a given line, one and only one line can be drawn parallel to the given line." But, try as they might, no proof was forthcoming. At last, early in the nineteenth century, Karl Friedrich Gauss and János Bolyai demonstrated that Euclid's postulate of parallels cannot be proved. By this time mathematicians had come to realize that the axioms of geometry are not self-evident truths, but merely convenient assumptions. Gauss, Bolyai and others were able to work out completely consistent systems of geometry without assuming the postulate of parallels, and thus they laid the foundations of non-Euclidean geometry.

MAX PLANCK

We have mentioned that one of Einstein's famous 1905 papers was based on Planck's quantum theory. Max Planck (1858–1947), who first proposed the theory in 1900, was one of the most eminent physicists of the twentieth century He was born in Kiel, Germany, and during most of his long life he was a teacher of mathematical physics in the German university system.

Quantum is a Latin word asking the question "How much?" and requiring the answer "So much." Planck's quantum theory is based on the idea that energy is transmitted in little particles, or bundles — each containing "so much" energy. Another way of putting it is that energy should be compared to a succession of bullets shot out of a machine gun — not to a steady stream of water shooting from a hose. Like the old-fashioned atom of Democritus and of John Dalton, the quantum of energy is represented as being indivisible. It is indicated in equations by the symbol *h,* called Planck's constant.

Einstein's theory that light is made up of particles did not make modern physicists abandon the doctrine that light consists of waves. Instead, they came to believe that in some cases light acts as if it were made up of particles, in other cases as if it consisted of waves. The French physicist Louis-Victor de Broglie (born in 1892) suggested in 1923 that this same dualism applies to electrons; that these should be regarded as particles and that their motion should be analyzed in terms of waves.

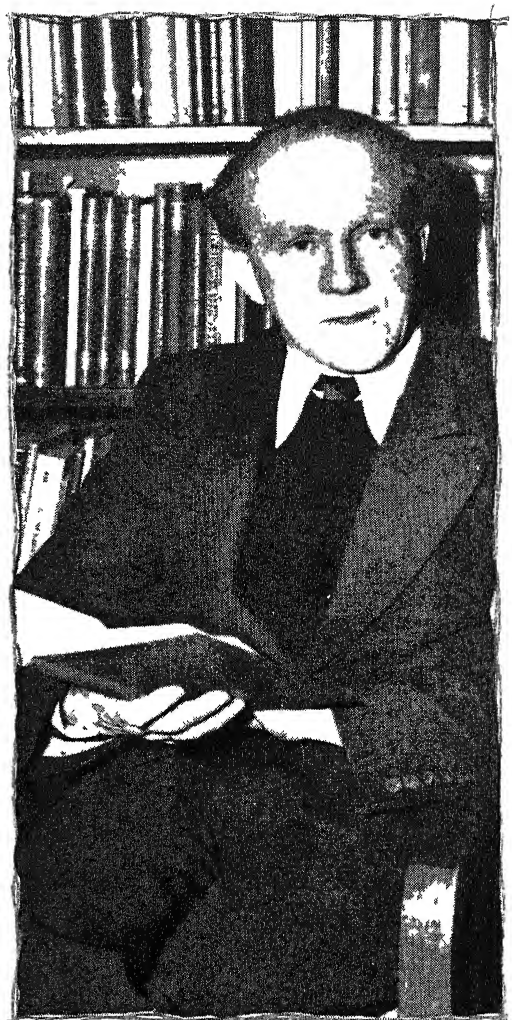
Because electrons are so tiny, the classical laws of mechanics do not apply to them To analyze their wave motion, Erwin Schroedinger (born in 1887), an Austrian professor of theoretical physics, developed a new system called quantum mechanics, or wave mechanics. It analyzed the wave motion of minute particles in accordance with the laws of probability. Schroedinger believed — quite correctly, it turned out — that the new wave mechanics would explain the mechanical events that take place inside the atom.

In the miracle decade of 1895–1905 and in the years that followed, so many old and apparently certain scientific beliefs were overthrown that scientists came to wonder whether there was really any such thing as certainty in science. Max Planck stoutly avowed that these gnawing doubts were unfounded. In his autobiography, published in 1948, he expressed his lifelong creed in the following words: "The fact that led me to my science and filled me with enthusiasm for it from my youth onwards . . . is that our laws of thinking coincide with the lawfulness [of] the external world . . . The external represents something independent of ourselves, something absolute . . . The search for the laws that hold for this absolute seemed to me the most satisfying task for the life work of a scientist."

Einstein holds that nothing in science is final

But Einstein denies the existence of any such absolute laws. He holds that there is no finality in science, that all scientific classifications are made for the sake of convenience and that they often result in error. Even the "certainties" of mathematics were denied by one of the greatest of all twentieth-century mathematicians, Jules-Henri Poincaré. "The axioms of geometry," said he, "are only definitions in disguise. That being so, what ought one to think of the question: 'Is the Euclidean geometry true?' The question is nonsense. One might as well ask whether the metric system is true and the old measures false."

The serious question of certainty in science was highlighted, in the early 1920's, by a young German physicist, Werner Heisenberg (born in 1901). He came forward with what he called an "uncertainty principle." He offered mathematical and logical proof that there are limits to both the accuracy and completeness of any bit of scientific knowledge. He demonstrated, for example, that it is impossible to specify at the same time the position and the speed of an electron within an atom. We cannot observe electrons, he said; we can only note their effects, as in the Wilson cloud chamber (see Index). Suppose that an electron collides with an object and leaves a trail that can be observed or measured. We can tell only where the electron was or how fast it was going at the moment of the collision. But we know nothing about the present speed or position of this particular electron, since both its speed and its position have been altered for all time as a result of the collision.


Wide World

WERNER HEISENBERG

A deep uncertainty — almost a sort of mysticism — clouds our modern concepts of the universe. We can never know with absolute certainty whence we have come,

what we are made of or whither we are bound. Thanks to Einstein and other physicists of the twentieth century, we have come to realize more clearly the true limitations of science. Though we can ask its offspring, technology, to build us atomic bombs and to harness atomic energy for our convenience and pleasure, it is now clear that we cannot ask science to answer the question "What is truth?"

THE RISE OF A NEW SCIENCE — ELECTRONICS

Control of electrons — those invisible particles of negative electricity that exist in the atom — has profoundly influenced man's civilization. When electrons flow along a definite channel — the insulated copper wire that leads to your toaster or vacuum cleaner, or the transatlantic cable lying on the ocean bed —they produce the phenomenon known as current electricity. We have already told of the many ways in which current electricity has been made to serve mankind.

In the present century, we have found new ways of putting electrons to work by causing them to flow through space in an electron tube or to make their way through the crystal framework of a transistor. (We shall tell you more about electron tubes and transistors later in this section.) The startling effects produced by such electrons have provided the basis of the science called electronics. This science has resulted in the development of radio, television, radar, the photoelectric cell, electronic welding, the electron microscope, electronic calculators and thousands of other useful devices.

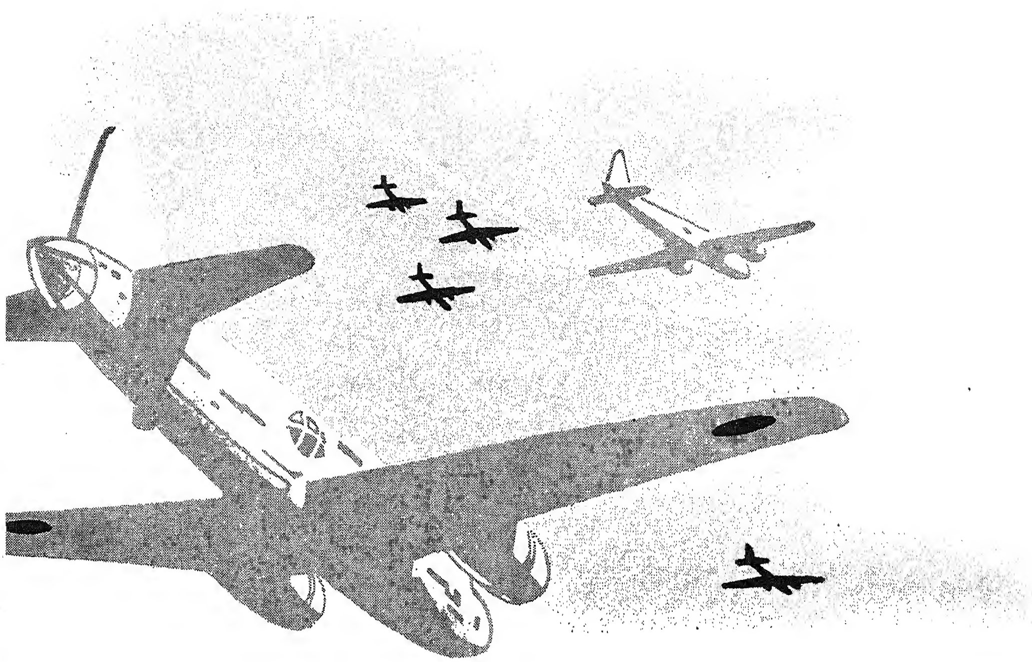
The theoretical researches that led to the development of electronics go back to the discovery of the electron. The word itself was coined about 1890 by the Irish physicist George Johnstone Stoney; but he did not use it in its modern meaning. It was not until several years later that the electron was finally identified. In April 1897, the eminent English physicist Sir Joseph John Thomson announced to a skeptical audience of scientists at a meeting of the Royal Institution that he had discovered certain hitherto unknown corpuscles of electricity. They were, he said, a thousand times smaller than the smallest atom known — the atom of hydrogen. These corpuscles were the particles of negative electricity that were to receive the name of electrons.

"The research that led to the discovery of the electron," Thomson said later, "began with an attempt to explain the discrepancy between the behavior of cathode rays [which we now know are nothing more than streams of electrons] under magnetic and electric forces . . . After long consideration of my experiments [performed by passing electrical discharges through vacuum tubes from which most of the air had been evacuated by pumps], it seemed to me that there was no escape from the following conclusions:

"That atoms are not indivisible, for negatively electrified particles [that is, electrons] can be torn from them by the action of electrical forces, by the impact of rapidly moving atoms, by ultraviolet light or by heat.

"That these particles are all of the same mass and carry the same charges of negative electricity . . . that they [electrons] are a constituent of all atoms."

For a time, many scientists were unwilling to admit the existence of electrons, since Thomson's demonstration had been based on pure theory. The Scottish physicist C. T. R. Wilson (born in 1869) did a great deal to convince his fellow scientists that these invisible subatomic particles really exist. Utilizing the apparatus called the Wilson cloud chamber, he succeeded in taking photographs of the paths of individual electrons through a cloud of mist. The American physicist Robert A. Millikan (born in 1868) likewise contributed to the knowledge of the electron. He measured its electric charge; he also calculated its mass, which turned out to be 1/1838th the mass of a hydrogen atom. Both Wilson and Millikan received the Nobel Prize in physics for their work.



Through electronic devices like radio and radar, surface ships can keep in touch with planes.

Students of electronics were confronted by many knotty questions — some still unanswered — concerning the nature and structure of matter. However, enough had been discovered to permit swift developments in practical electronics.

The great American inventor Thomas A. Edison pointed the way. In 1883 he made a special electric-light bulb, in which a little metal plate was sealed near the filament (the wire loop). A current of electricity was made to flow through the space inside the bulb between the wire and the plate, producing a faint blue glow. Edison was unable to explain this striking phenomenon, which came to be known as the Edison effect. As he was busy with other inventions at the time, he did not pursue the matter further.

In the early 1900's, an English electrical engineer, John A. Fleming (1849–1945), built a special kind of tube based on Edison's modified light bulb, and he began to study carefully the flow of current between the filament and the plate. He came to realize that the Edison effect is due to the heating of the filament, which causes electrons to "boil off" into space from the metal. He found that his tube, which he called a valve, was a good rectifier of electricity — that is, it would let current flow in one direction only, when the plate was positive. Fleming used his valve as a detector for wireless telegraph signals. It was the first electron tube.

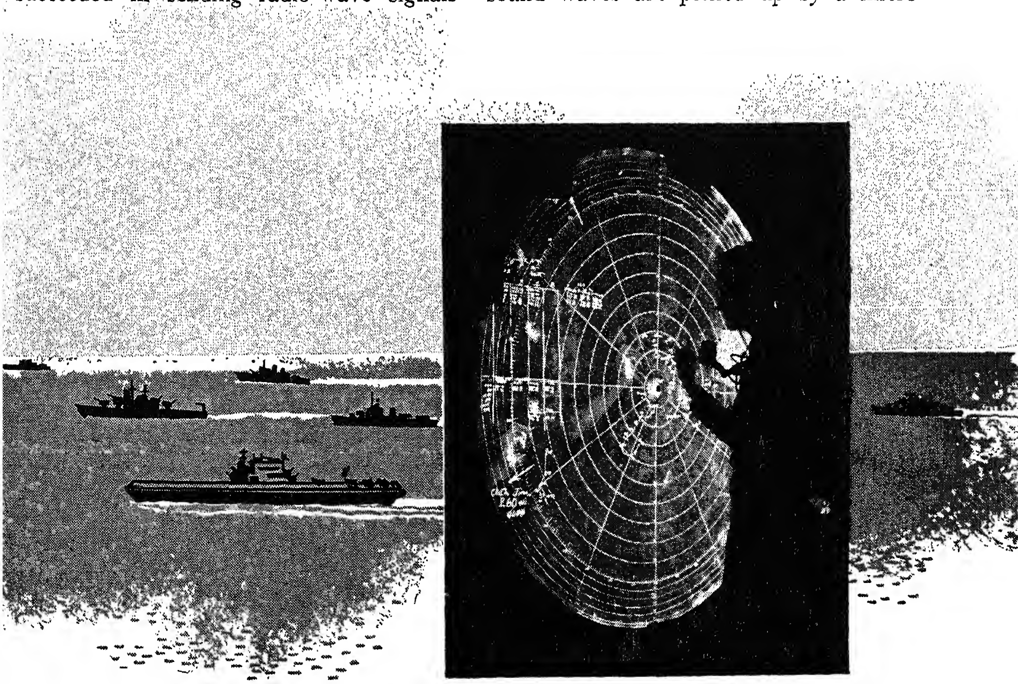
The most important improvement in

the electron tube was made in 1907 when an Iowa-born inventor, Lee De Forest (born in 1873) added a grid, or wire mesh, to Fleming's tube; the grid was mounted between the filament and the plate. Electron tubes today are based on this early model of De Forest's. The grid in an electron tube is negatively charged; since electrons also have a negative charge, they tend to be repelled from the grid and only a small number reach the plate. By increasing or diminishing the negative electric charge on the grid, it can be made to regulate the flow of electrons to the plate. This means that not only can electrons be sent through space but that their flow can be controlled with great precision.

De Forest called his electron tube an audion tube; it was also called a triode, since it was made up of three elements (filaments, plate and grid). The audion tube was soon applied to the transmission and reception of radio waves. As we saw in a previous chapter, Marconi had already succeeded in sending radio-wave signals through space. The audion made it possible to detect these signals far more effectively than ever before and also to amplify them. De Forest himself was responsible for more than three hundred inventions in the field of electronics. He designed the first high-power radio stations for the United States Navy and sent the first news broadcast in 1916.

Most of the electronic devices of the twentieth century are ingenious applications of the electron tube. Today there are hundreds of different kinds of these tubes, some as small as a thimble, others as large as a man. Besides detecting and amplifying radio signals, they can turn alternating current into direct current and they can switch independent circuits on and off. A special kind of electron tube, called a photoelectric cell, can transform light into electricity.

Perhaps the best known of all electronic developments are radio (once called radio telephony) and television. In radio, sound waves are picked up by a micro-



U. S. Navy photo

Radar provides long-range detection of airborne as well as of surface objects.

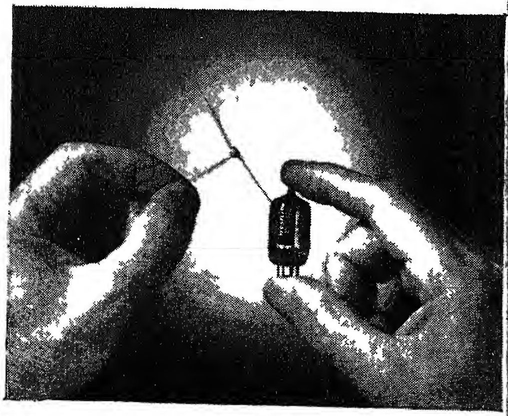
phone and are transformed into electrical current of varying intensity. The current is amplified and then transmitted through space in the form of high-frequency radio waves. The radio receiver catches these waves, amplifies them and by means of the loud-speaker transforms them into sound waves again. Lee De Forest, inventor of the audion tube, contributed much to the development of radio. So did Irving Langmuir, who perfected a more efficient electron tube, and Edwin H. Armstrong, who developed frequency modulation (FM), a system of radio broadcasting that reproduces sounds with utmost fidelity and practically eliminates static. (See the article Radio Communication, in Volume 3.)

In television, light waves are transmitted into electric current of varying strength through the medium of the photoelectric cell. The current is amplified and sent out as high-frequency radio waves. The waves are picked up by the television receiver, amplified and changed into the original light pattern. In the article Practical Television in Volume 10, we show how television transmitters and receivers operate. Among the pioneers in the development of television were Paul von Nipkow, Philo T. Farnsworth, Vladimir Zworykin and Allen B. Du Mont.

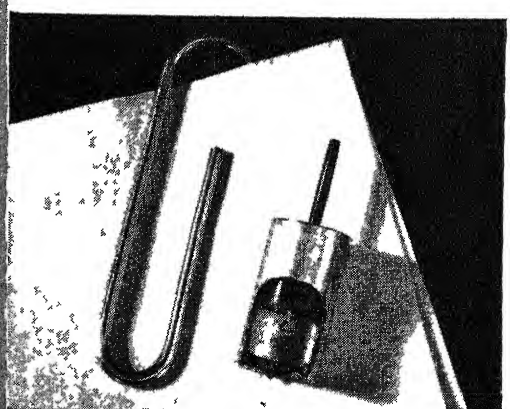
Another electronic device that uses radio waves is radar. The name is an abbreviation of RAdio Detecting And Ranging — four words that tell what radar is and what it does. A beam of radio waves transmitted from a radar set travels away from the set with the speed of light. When this beam hits a solid object in its path — an airplane, say, or a ship — it is reflected back (also at the speed of light) to its source, and it shows up on a screen. As one beam after another hits various parts of the object and bounces back to the screen, the operator gets a rough picture of the object. Radar does more than reveal the mere existence of the object; it also indicates its direction and its distance from the radar set.

Radar points out obstacles in the path of ships and planes; it serves as a sky policeman, watching sky traffic at all heights as it enters or leaves congested regions near an airport; it takes command of planes as they come in for a landing.

It is useful in war as in peace. In fact, practical radar was a product of World War II, and it is credited with having saved England in the dark hours of 1942. Radar scouting, a new type of defense measure, warned the Royal Air Force pilots of the coming of enemy planes and thus helped to foil the Nazis' efforts to overwhelm Britain by mass bombing. It also



The transistor is one of the most important electronic developments in recent years. The junction transistor, shown above (left), consists of a bit of germanium set in a blob of plastic.



Both photos, Bell Tel. Labs. Inc.

Here we see a point contact transistor, in which two hair-thin wires are set upon a tiny speck of germanium. The casing in which the transistor is housed is smaller than a paper clip.

helped to win the fight against German submarines because it enabled Allied destroyers to detect their presence.

The development of radar was based chiefly on the preliminary researches of A. H. Taylor and L. C. Young at the United States Naval Research Laboratory in the early 1920's. These two scientists sent out high-frequency waves, and by analyzing the echoes were able to detect the presence of ships passing on the Potomac River. Other important figures in the development of radar were the British physicist M. L. E. Oliphant, at the University of Birmingham, and Dr. Lee A. Du Bridge, of the Massachusetts Institute of Technology.

Electronics has provided mathematical calculators that play an important part in scientific research. Simple electronic calculating devices were in use as early as 1925, but they were much more fully developed during World War II. The first large-scale electronic calculator was set up at the University of Pennsylvania in 1946. Two years later the IBM (International Business Machines) Selective Sequence Electronic Calculator — a machine with a superhuman memory — was introduced. Even more startling calculating machines have been developed since that time. It is important to note that these "electron brains" cannot disgorge any more information than human brains originally put into them.

An electronic device that is extremely valuable to scientists is the electron microscope. It uses a source of electrons in place of a source of light in order to provide an enlargement of a given object. Electron beams are focused by a series of magnets. After passing through the object that is to be enlarged, they produce an image on a fluorescent screen. The screen can be replaced by a photographic plate for direct photography.

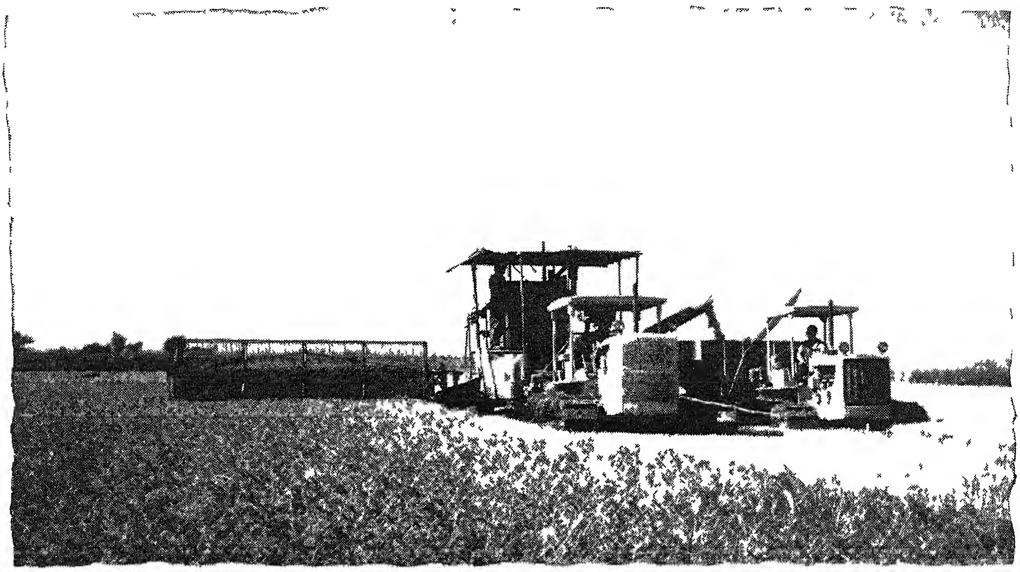
An important clue to the focusing of electron beams was provided about 1931 by the German physicist H. Busch. The first electron microscope was built in 1932 by M. Knoll and E. Ruska. A later model, built in the United States by M. Knoll, E. Ruska and Vladimir Zworykin, in 1938, magnified up to 30,000 diameters; it marked a great advance over the most powerful optical microscopes magnifying 2,500 diameters or less. Today's electron models can magnify beyond 200,000 diameters.

We have already mentioned the photoelectric cell, or electric eye. One form of this cell consists of an electron tube whose cathode is coated with a light-sensitive substance such as cesium. The light that strikes this substance is transformed into a weak electric current, which varies in intensity according to the strength of the light source; this current can be amplified and relayed. Other types of photoelectric cells are based on the same principle. The electric eye is used in television; it also serves in talking-picture equipment, in door-opening devices, in burglar alarms and in counting, sorting and inspecting. The development of the photoelectric cell was made possible through the researches of Wilhelm Hallwachs, Philipp Lenard, J. J. Thomson and Albert Einstein. (We describe the cell in detail in Volume 3, in the chapter called The Electric Eye.)

The transistor — a rival of the electron tube

Until recently, all electronic devices were based on the electron tube. Lately, however, a new type of electron-controller — the transistor — has been developed. It consists of a tiny speck of germanium embedded in a blob of plastic, or of a small metal tube in which two hair-thin wires make contact with a fragment of germanium. In The Mighty Midget of Electronics, Volume 2, we show how the transistor works. It is so small that a hundred can be held in the palm of the hand, yet it can perform most of the tasks of the electron tube. The transistor, when fully developed, will doubtless be used extensively in all sorts of electronic devices.

Electrons have always swirled in matter — in man and in the physical universe in which he dwells. But electrons on the march, regimented and controlled by electron tubes and transistors, are a twentieth-century contribution to the welfare of man.



Caterpillar Tractor Co.

Machinery at work on the farm, harvesting rice. The diesel tractors shown above are hauling a combine and "bankout wagon."

AGRICULTURE BECOMES SCIENTIFIC

In modern times scientific research and technology have converged upon the oldest of industries — agriculture. Clinton P. Anderson, former Secretary of Agriculture of the United States, eloquently described the remarkable advances that have resulted. "I have watched," he said, "the onward surge of science in farming. We now have tractors and attachments that pull our heavy equipment and can dig holes, grade roads, clean barnyards, lift loads and grind feed. We have hens that lay twice as many eggs as chickens did a few years ago. We have alfalfa, wheat, flax and oats that are wonderfully resistant to disease. We can buy a kind of chemical that kills weeds and, used in another way, stimulates the growth of fruits and vegetables. We have new kinds of sheep and cattle and hogs that give us more wool or meat or bacon; and we have surer ways to keep them healthy and free of pests. Insecticides make our houses and barns more sanitary and comfortable. We have hybrid trees, hybrid corn and hybrid onions of almost incredibly high yields . . . The corncobs that we used to throw away or burn up a few years ago have been used in industry. Many of the mysteries of the good earth have been disclosed to us in a few years of agricultural research; and we use this knowledge to till the soil for its welfare and ours."

The United States Department of Agriculture has been in the forefront of progress in scientific agriculture since the latter part of the nineteenth century. On its staff have been such men as Theobald Smith, who showed that ticks carry the germs of Texas fever to cattle; Marion Dorset, who discovered the virus of hog cholera, which was bankrupting Iowa; Harvey W. Wiley, a crusading physician who put through the Congress of the United States in 1906 the first Pure Food and Drug Act; and the entomologists Charles V. Riley and Albert Koebele, who brought in new insects to destroy the old insects that were ruining crops. Today, the United States Department of Agriculture has magnificent research laboratories at Beltsville, Maryland, and field stations throughout the United States.

There is hardly any field of agriculture that has not been affected by scientific research. Scientists have carefully analyzed the chemical elements and compounds present in soils and necessary for the

growth of plants. They have proved the importance of bacteria in helping to convert insoluble mineral substances into forms that can be assimilated by plants. Through analysis involving what is known as the *p*H value, soil chemists can accurately determine the acidity or alkalinity of soils. The chemical industry has produced synthetic fertilizers, like ammonium sulfate and calcium cyanamide, to supplement natural fertilizers, such as potash and barnyard manure. It has developed powerful insecticides, such as DDT, TDE and benzene hexachloride, and effective weed killers, like 2,4-D and sinox. Modern scientific methods have also been applied to conservation practices and to the irrigation and drainage of the fields.

A great deal of scientific progress in agriculture has been due to the rapid development of genetics in the present century. Plant and animal breeding have a long history of their own, but it is only within the present century that scientific — genetic — principles have been applied to age-old practices. The man who did the most to put genetics on a scientific basis was the Austrian monk Gregor Mendel (1822–84). Experimenting with the common garden pea, he showed that heredity could be understood by means of simple mathematical ratios involving dominant and recessive characteristics in plants and animals. He presented the results of his research in a paper which was read to the Natural History Society of Bruenn in February and March 1865 and which was published in the proceedings of the society in 1866. Unfortunately, the world of science paid no particular attention to Mendel's paper until the year 1900. At that time it was independently rediscovered by several researchers in genetics, including Hugo De Vries, Karl Correns, Erich Tschermak and William Bateson. Mendel's paper gave powerful impetus to the study of genetics.

The Austrian monk had not been able to explain just how hereditary characteristics are transmitted from parent to offspring. This explanation was provided in the second decade of the twentieth century by a group of Columbia University investigators headed by the Kentuckian Thomas Hunt Morgan (1866–1945). He used the fruit fly *Drosophila melanogaster* in his research because this insect reproduces so rapidly that many generations can be traced in a short space of time. In 1916, Morgan announced: "We now know how the factors of heredity carried by the parents are sorted out to the germ cells." He showed that these factors are carried in bodies called genes, which are located in the chromosomes of plant and animal cells. There are special sets of genes for types of leaves and flowers, for color of hair and eyes, for length of wings and for thousands of other traits. Morgan won the Nobel Prize in 1933 for his work on genes.

Another important advance in genetics was made by Herman J. Muller (born in 1890), a biologist at the University of Indiana and, like Morgan, a Nobel Prize winner. Muller showed that when germ cells are exposed to X rays or other kinds of radiation, the genes often produce characteristics different from those which might have been expected.

These advances in the science of genetics have proved immensely helpful to the farmer. To quote the plant geneticist Ernest Robert Sears: "We can use nature's laws to produce more productive, better adapted and healthier plants and animals. Many of our present-day crops and certain of our breeds of livestock owe some of their most desirable or even vital characteristics to the scientific breeder." Plant geneticists have developed hybrid corn that yields about 25 per cent more calories to the acre than ordinary corn and that is adapted especially for resistance to disease and for machine harvesting. They have produced hybrid onions that are three times heavier than ordinary onions and that mature more rapidly, too. They have bred into common wheats resistance to the dread disease black stem rust.

Applied science, or technology, has developed machines that have contributed greatly to agricultural progress. It would take many pages to list all the machines (many of them perfected in comparatively recent times) that are used on the farm.

They may be classified as follows:

(1) Power and transport machines. — Tractors, automobiles, motor trucks, stationary gasoline engines, electric motors.

(2) Machines for preparing land for planting. — Plows, harrows, field cultivators, soil pulverizers, stalk cutters, floats.

(3) Machines for planting, seeding and applying fertilizers. — Row-crop planters, grain drills, broadcasters, transplanters.

(4) Machines for cultivating crops. — Tractor-drawn and horse-drawn cultivators, equipped with shovels and sweeps.

(5) Machines for harvesting crops. — Haying machines, mowers, combines, corn pickers, cotton pickers, potato diggers, bean harvesters and so on.

(6) Machines for preparing crops for the market and for farm use. — Ensilage cutters, forage cutters, feed grinders, corn huskers, corn shellers, fanning and cleaning mills and so on.

(7) Machines for handling livestock and livestock products. — Cream separators, milking machines, churns, freezers, incubators, brooders.

(8) Machines for controlling insect pests and disease. — Sprayers, dusters.

(9) Miscellaneous farm machines. — Pumps, stump pullers, ditchers, terracers, manure balers, weed burners, limestone pulverizers and so on.

Power to operate these machines is supplied in various ways. Some are still operated by the muscles of man or of such farm animals as horses and mules. Internal-combustion motors (gasoline and diesel engines) have replaced animals on many modern farms. The power of moving air is utilized in windmills, which pump water or drive generators. Electricity is being used on farms to an increasing extent, particularly in recent years. Rural electrification of the United States was practically complete by 1950.

Scientific technology has made it possible to utilize vast quantities of farm products and wastes as raw material for industry. The first plastic material — Celluloid — was prepared in 1869, largely from the cellulose contained in cotton. The inventor of Celluloid was John Wesley Hyatt, a young American printer. He had sought to develop a substitute for ivory in the manufacture of billiard balls. Celluloid was not satisfactory for this purpose, but it proved to be a fine substitute for ivory and bone in the manufacture of combs, buttons, hand mirrors, brushes and so on. Today not only cellulose but a good many other farm products are used in the manufacture of plastics. For example, casein (from skimmed milk) yields plastic buttons, beads and buckles; plastics derived from soybean meal are used for steering wheels, gearshift knobs and other automobile parts.

The use of farm products and even farm wastes for industrial purposes has been powerfully advanced by the rise of chemurgy — chemistry applied to agricultural raw materials. The word "chemurgy" ("chemistry at work") was coined in the 1930's by Dr. William J. Hale, a Michigan research chemist, who is credited with being the father of chemurgy. But the beginnings of this science go back to the previous decade.

A few enterprising men began to promote the idea of chemurgy in the United States in the 1920's, when farm surpluses were a national problem. They pointed out that straw, stalks and culls (rejected parts of the crop) would yield abundant returns to the farmer if ways and means could be found to use them in industry. Research chemists set to work on the problem. In the spring of 1935, the National Farm Chemurgic Council, Inc., was established, with headquarters at Columbus, Ohio. Since that time, chemurgic research has been carried on on a wide scale; new uses for farm wastes are constantly being found.

Science and technology have added bountifully to man's agricultural resources, but, unfortunately, they have not been applied widely enough. There are still vast areas of the world where age-old farming practices impoverish the soil, hold down production and keep nations and peoples miserably poor.

SCIENCE THROUGH THE AGES is continued on page 3709.

THE VARIOUS CEREALS

The Gift of Ceres, the Mythological Goddess of Agriculture and the Harvest

ONE OF THE OLDEST FORMS OF HUMAN FOOD

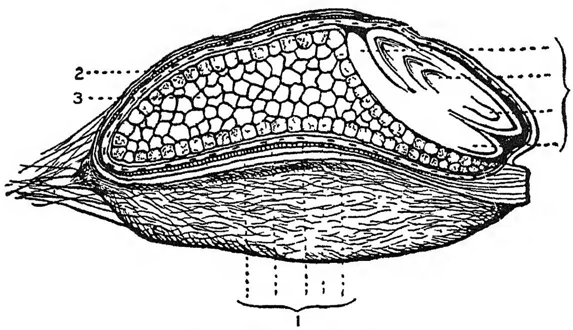
GRAINS or cereals are one of the oldest forms of human food and have been in constant use ever since man, developing wisdom and foresight, ceased from his wandering life and began to cultivate the soil. Cereals are so named from Ceres, the goddess of agriculture and of the harvest, who was conceived by the ancient Greeks and Romans as the cause of the mysterious evolution of life out of the seed. Mythology reveals that it was Ceres who first inspired mankind with an interest in property and the ownership of land, who created the feeling of patriotism and the maintenance of law and order. The introduction of civilization may thus be traced to grain production, since the custom of living in settled communities originated from the necessities of agriculture. Many of the ancient wars in history were waged in an effort to gain access to territory suitable for grain growing, since famine was a much dreaded menace owing to the difficulty of securing an adequate supply of this very important article of food.

The cereals are the farinaceous seeds of different species of the grass family. These plants pack starch, protein, oils and other elements needed for the growth of the young plant into the seed, which is the portion used for human food. The grains most commonly cultivated and used on this continent are wheat, oats, corn or maize, barley and buckwheat. How to convert these seeds into wholesome, palatable food was the task allotted to primitive woman, and she had to devise some method whereby the grain could be crushed, the husk removed and the meal portion separated. Various devices were used for this purpose, and the first real grinding was done by means of two stones, a large one, slightly concave, which held the grain, and a smaller one which was rubbed back and forth, thus crushing it. The operation of these primitive mills was part of woman's daily household tasks, and is done even today in very much the same crude way in some parts of Africa and South America.

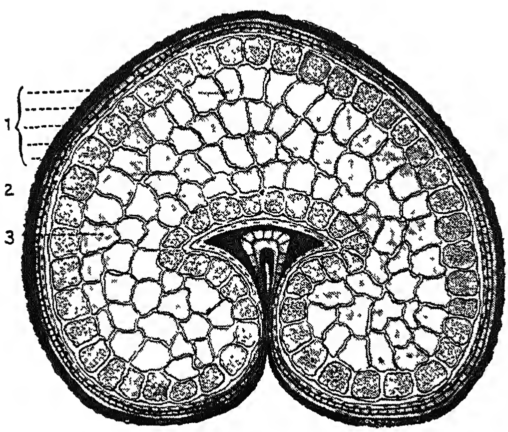
Wheat was no doubt the first cereal thus prepared for human use, and hence whole wheat bread was probably the first made since the entire grain was ground up into meal. Bread has long been called the "staff of life", possibly because, with the exception of milk, it was found to support life better than any other single food. The method of preparing bread in primitive times was very simple indeed, the whole meal being merely mixed with water and then baked on hot stones or in hot ashes, producing a hard cake or biscuit. Although unleavened bread was used in primitive times, the use of leaven is itself very ancient, dating back to the time when the Israelites were sojourning in Egypt. The first leavening agent was yeast, contained in a piece of dough reserved from the previous baking, although how it first became known is not revealed in historic records. It is a well-known fact that wild yeasts are present in the atmosphere, and so doubtless their leavening power was accidentally discovered by some primitive housewife unwittingly leaving the flour and water mixture exposed to the air and then afterwards baking it, thus producing a lightened loaf.

The admirable structure of a tiny grain of wheat

Wheat is probably the most extensively cultivated and the most universally used grain in America and it is also more widely milled, furnishing a larger number of products than any of the other cereals. While the various cereals differ somewhat in their chemical composition, most of them are similar in structure; hence a study of the formation and milling of wheat will make it easy to understand the production of flour from all of them.



Longitudinal Section



Transverse Section
1 bran
2 aleurone layer.
3 endosperm.
4 germ

DIAGRAM OF A GRAIN OF WHEAT

In order to have a clear understanding of the value in the diet of the different wheat products it is necessary to know what part of the kernel each contains. An examination of the structure of a kernel of wheat will serve to make further discussion clearer (see the diagram). Surrounding the grain of wheat is the husk or fibrous outer layer, but this is not used for human food since it is so very coarse and tough. Lying immediately under this outer coat is the bran, which is composed of several distinct layers and, with the aleurone layer, constitutes about 15 per cent of the entire grain.

Directly beneath the bran is found a single layer of large cells full of granular material which is rich in protein and phosphorus and which completely surrounds the flour or endosperm portion of the grain and is known as the "aleurone" layer. The whole central portion of the seed, or 83.5 per cent, is the endosperm or flour portion which furnishes food needed for the embryo plant when the seed germinates.

The endosperm consists of thousands of cells, the walls of which are cellulose material; while the contents consist of innumerable starch granules together with protein materials, chiefly glutenin and gliadin, which when kneaded with water form gluten, the tenacious elastic material so important in bread making. The germ or embryonic plant comprises 1.5 per cent of the grain and is rich in oils, mineral constituents and vitamins.

The milling of flour, the ancient and the modern processes

In the old-fashioned process of milling, the entire kernel was ground between stones and the meal thus obtained sifted through screens covered with bolting cloth. Owing to the tough, fibrous nature of the bran, the greater part of it did not pass through the bolting cloth, but some, however, was pulverized, and hence could not be separated from the flour. In addition, the flour contained most of the germ, which owing to its high fat content greatly impaired the keeping qualities of the product. This old milling process gave what has been termed "entire" wheat flour, but owing to its rapid deterioration there was need for a better method, and so we find the roller process almost entirely replacing it toward the end of the 19th century. In the modern or roller mill process

a great many grades of flour are obtained, as against one grade in the old process. By this new method the wheat, after being thoroughly cleansed, is passed between a pair of corrugated rollers which simply break the kernel open; the whole of this product is then sifted through bolting cloth and the coarse part which does not pass through is sent to another pair of rollers set somewhat closer together. After the second crushing, the product is sifted again and the branny part returned to other rollers. This process is repeated four or five times until practically all the starchy materials are separated from the bran. The flour thus obtained is practically free from both bran and germ and its keeping qualities have been improved, but unfortunately with a serious loss in food value.

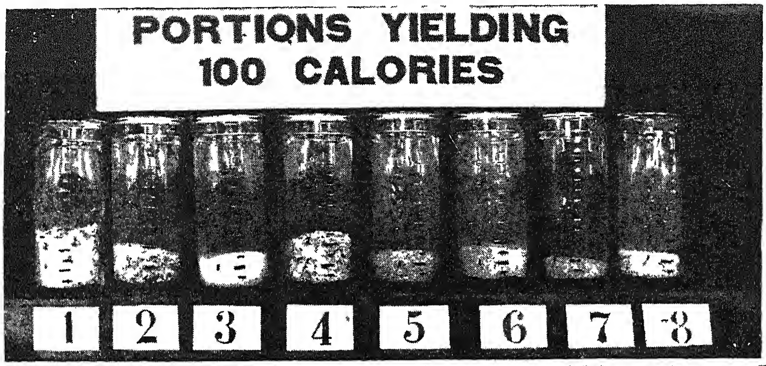
With each sifting the greater part of the endosperm is left in a coarse granular form which when purified may go to make farina, which is sold under a variety of names, such as "Cream of Wheat", a breakfast cereal. The bran separation is never quite complete in this process, and even the purest commercial bran contains about 17 per cent of white flour and germ. The germ also is not completely isolated in the milling process, and it has been estimated that only about 50 per cent of the mill product sold as germ is pure germ, the remainder being flour and bran in about equal proportions. Graham flour should be whole wheat finely ground but not sifted, thus containing all the nutrients of the entire grain. Entire wheat flour should contain the entire kernel except the coarsest of the bran. Many so labeled do not.

Value of the wheat and the other cereal proteins

Feeding experiments carried on by investigators with vigorous young rats have shown that the proteins of the wheat germ are more efficient for growth than those of the entire kernel, that the proteins of bran are apparently equal to those of the germ and that the proteins of the entire kernel are better than those of the flour portion alone. It was found that young rats failed to grow on diets in which the protein was entirely furnished by white flour, although the diet was adequate in every other respect, and was apparently sufficient to maintain adult rats. When the protein, however, was supplied by either the germ or the bran, the young rats grew, thus showing these proteins were more efficient for growth. Hence it is evident that the proteins of the germ and bran are better than those of the endosperm. Although the rats grew fairly well when fed the proteins of the entire grain, it was found necessary to supplement the diet with a better grade of protein in order to obtain normal growth. When milk, sufficient to supply one-third of the protein, was included in the diet, normal growth was obtained. These experiments indicate that when white bread only is used in a child's diet, the protein deficiency may be off-set by using an adequate amount of milk. The proteins of oats, maize and rice have been found to be of no better quality than those of wheat, and we may conclude that those of seeds will not support normal growth and will need to be supplemented by foods, such as milk, containing a better grade of protein.

The digestibility of cereal proteins as shown by experiment

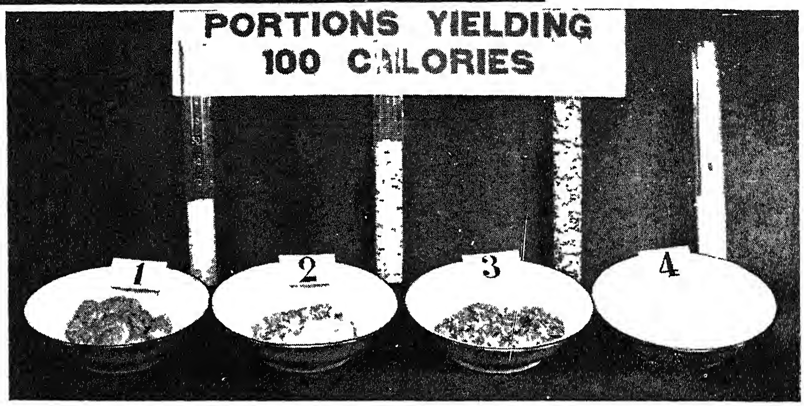
The proteins of the bran layers of the wheat kernel are enclosed in cells having thick walls which are not readily digested unless broken down and softened by cooking, hence the proteins of this region are not readily available for human food. Digestion experiments on healthy men have corroborated this. Bread made of white flour, entire wheat flour and Graham flour was used by the investigators for this experiment, and the average percentage of proteins digested is given as follows: 88.6 per cent of the protein of white flour was digested, 82.6 per cent of entire wheat flour and 74.9 per cent of Graham flour. Cattle and poultry on the other hand have digestive organs that can take care of tough cellulose and so are able to utilize these proteins more completely. The solubility of the proteins of the whole kernel seems to be increased by long cooking, and so in breakfast cereals made of the whole grain, such as rolled or cracked wheat and oatmeal or rolled



100-CALORIE PORTIONS OF VARIOUS RAW CEREALS

1. Rolled Wheat.
2. Cracked Wheat.
3. Farina.
4. Rolled Oats.
5. Oatmeal.
6. Cornmeal.
7. Rice.
8. Barley.

All are in 8 oz jars.



100-CALORIE PORTIONS OF RAW AND COOKED CEREALS

1. Cornmeal.
2. Rolled Oats
3. Flaked Wheat.
4. Farina

The corresponding raw cereal is behind and to the right (in 100 c.c graduates) of the cooked cereal (in cereal saucers).

oats, the total amount of soluble solids may be increased by the cooking process. The results of an experiment made to confirm this fact are reported as follows:

ROLLED OATS

Time Cooked	Method of Cooking	Soluble Protein	Total Soluble Solids
		%	%
Uncooked	—	0.86	8.43
20 minutes	Boiled	0.89	14.95
2 hours	Boiled and then cooked over hot water	1.57	18.79
5 hours		2.28	29.93
8 hours		3.39	34.30

This marked increase in soluble solids on prolonged cooking undoubtedly facilitates ease and slightly improves completeness of digestion, for the investigator found that 77.7 per cent of the protein was digested when oats were cooked for 20 minutes, when for 8 hours, 82.6 per cent. In addition, the flavor of these whole cereals is greatly improved, making them more palatable and hence digestible.

Mineral constituents

The amount of calcium, phosphorus and iron found in a 100-Calorie portion (see figures), or an average serving of cereals is given by H. C. Sherman in his "Chemistry of Food and Nutrition" as follows:

MINERAL CONTENT IN 100-CALORIE PORTIONS

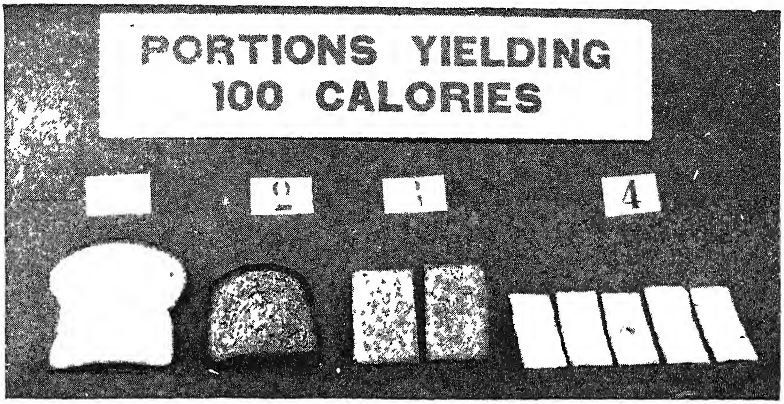
Cereal Product	Calcium Gms.	Phosphorus Gms.	Iron Mgms.
Entire wheat kernel .	0.013	0.118	1.40
Graham flour . . .	0.011	0.101	1.00
White flour	0.006	0.026	0.23
Farina	0.006	0.035	0.22
Oats	0.017	0.099	0.96
Cornmeal	0.005	0.053	0.30
Rice—polished . .	0.001	0.027	0.26

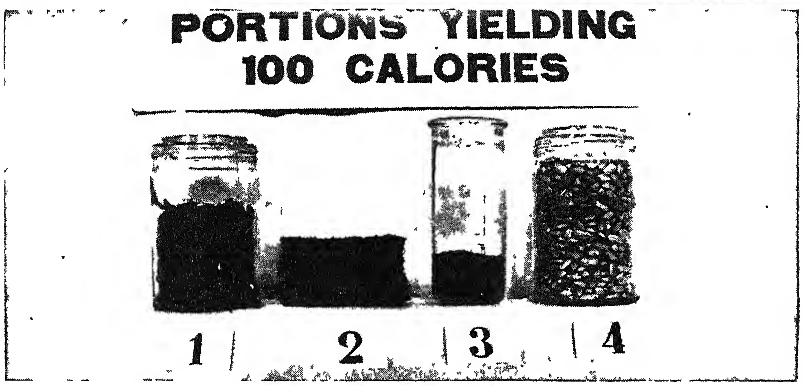
Calcium. The wheat kernel as a whole is exceedingly poor in calcium, and in the process of milling the white flour, more than half the calcium is removed. When vigorous young rats were fed with a diet in which whole wheat or other whole cereals

100-CALORIE PORTIONS OF BREAD AND CRACKERS

1. White bread.
2. Graham bread.
3. Graham crackers.
4. Saltines.

The slice of Graham is $3\frac{1}{4} \times 3\frac{1}{4} \times \frac{3}{4}$ inch, the slice of white bread is $3\frac{1}{2} \times 4 \times \frac{1}{2}$ inch; they are the same weight.





100-CALORIE PORTIONS OF READY-TO-SERVE CEREALS

1. Toasted Cornflakes in pint sealer.
2. Shredded Wheat biscuit.
3. Grapenuts in 8 oz. jar.
4. Puffed Rice in pint sealer.

was the sole source of calcium — the diet being adequate in every other respect — the results obtained revealed the inadequacy of the grain with regard to calcium, since the rats failed to grow. When calcium salt was added to the diet, growth became normal again.

Phosphorus. The wheat kernel is the richest of all the cereals in phosphorus. A 100-Calorie portion of the entire kernel gives 0.118 grams of phosphorus but the same portion of farina yields only 0.035 grams or about one-third as much, and white flour gives still less. Of the other common cereals, oats come next in order, then cornmeal and pearled barley have only about one-half as much as wheat, while polished rice is the poorest of all.

Iron. Reference to the table shows that wheat is the richest of the cereals in iron, but also reveals the great loss which takes place during the milling process and the importance of including the whole cereal in the daily dietary. While oats do not furnish as much iron as wheat does, they contain three times as much as a similar weight of cornmeal and four times as much as polished rice — in fact cornmeal and polished rice are deficient in iron. In cereals in general, the ash or mineral constituents are concentrated very largely in the germ and outer layers or bran coats, and since these two portions of the kernel are frequently removed in the process of manufacture, there is consequently a very great loss in phosphorus and iron, which are so essential to an ideal dietary.

Vitamin content

Vitamin A is present in a small amount in the wheat germ, although it is practically lacking in the bran and endosperm. The kernel as a whole is therefore deficient. In fact the wheat kernel is so poor in its content of this vitamin that if used as the sole source of vitamin A it fails to maintain growth in animals. This is generally true of all the cereals, and hence a cereal diet must be supplemented by foods rich in vitamin A, such as milk, butter fat, egg yolk and green leafy vegetables, in order to secure optimum well-being.

Vitamin B was discovered through the study of beri-beri. Investigations revealed the close connection between a diet consisting very largely of polished rice and the occurrence of the disease. Experimental work with pigeons showed that a similar disease — polyneuritis or beri-beri of fowls — was induced when the diet consisted of white or polished rice, but did not occur when whole rice or rice partially milled, but still containing the inner bran coat. was used. It was not long before it was discovered that when rice polishings or the bran was added to the diet of polished rice the disease was cured.

Since we know vitamin B is found in rice polishings it is natural to expect to find it in the bran and germ of wheat. Investigators, using healthy young rats, have demonstrated the fact that the wheat kernel is quite rich in this vitamin, and when wheat kernel forms even 15 per cent of the diet, sufficient vitamin B is furnished to enable the rats to grow to full adult size. When, however, 60 per cent of the diet is composed of white flour there is not sufficient vitamin B to produce normal growth in the young. It is also known that a diet consisting too largely of white flour or white bread may cause beri-beri.

An instance of this occurred in the late war when, during the siege of Kut-el-Amara in Mesopotamia, the rations became limited. The disease was reported among the British soldiers but practically no cases were found among the native troops. The diet was composed principally of bread and canned beef but the British soldiers had bread made of white flour while the bread of the natives was made of a flour containing more of the bran and germ. When this latter bread was given to the British soldiers the disease was controlled until the siege was lifted and a more varied diet could be secured.

Hence it is readily seen that the value of cereals as a source of vitamin B depends on the part of the grain that is used. Polished or white rice is lacking in it while brown rice is a good source. Whole cereals, too, are a good source and as such should be included in the daily dietary.

Vitamin C. Scurvy has long been associated with a limited diet consisting principally of bread or other grain products and meat or fish. When, however, the diet included fresh vegetables and fruits the disease became less common. Investigators found that guinea pigs fed exclusively on bread or grain developed scurvy, while those fed on carrots, cabbage and hay appeared relatively immune, showing that cereals do not contain vitamin C. The whole cereals then have no value as antiscorbutics nor are they a good source of vitamin A but are rich in vitamin B.

Cereal breakfast foods

The breakfast foods found on the American table at the present time are a modern invention, but they may all be traced back to the old-fashioned porridge which was made by simply boiling the coarse cereals in water for a very long time. The old-time porridge was usually made of oat or wheat grains merely husked and cracked, but with the development of machinery these coarse grains were replaced by the so-called "rolled" oats and wheat, in which part of the cooking was done at the factory. This was of advantage to the housewife for the older products required a very long, slow cooking to make them palatable, which eventually became a problem as the cost of fuel increased. In response to the demand for breakfast cereals which could be easily and quickly prepared we have an ever increasing number and variety of these products on the market. No class of foods, perhaps, has been so widely advertised as these, nor had such astonishing claims made for them, yet their popularity seems assured for they are palatable and afford a pleasing variety in the diet.

The grains commonly used in the preparation of the modern breakfast cereals are oats, wheat, corn, barley and rice, and although some of the preparations do not contain the whole kernel, others may be a combination of several of them. The following table shows the distribution of calories in a 100-Calorie portion of some of these cereals in common use and it may be noted that one ounce is the approximate weight of such portions when dry.

Cereals	Calories from		
	Protein	Fat	Carbohydrate
Uncooked Products			
Barley	9.5	3.0	87.5
Cornmeal	10 0	5.0	85.0
Farina—Cream of Wheat	12.0	4.0	84.0
Hominy	9 5	1.5	89 0
Oats—Rolled or Oatmeal	16.0	16.0	68.0
Rice	9 0	1.0	90.0
Wheat—rolled or cracked	12.0	4.0	84.0
Ready-to-serve Products			
Grapenuts	12 5	2.0	85.5
Puffed Rice	6.0	1.0	93.0
Shredded Wheat	11.5	3.5	85.0
Toasted Cornflakes	6.0	4 0	90.0

All of these cereals may be grouped into one of two classes: (1) uncooked; (2) ready-to-serve. The cereal foods requiring cooking include oatmeal, cracked wheat, farina, cornmeal, hominy and rice. Rolled oats and flaked wheat, the first to be introduced among modern breakfast cereals, also belong to this class, because although in the process of manufacture they are slightly cooked, yet not sufficiently to class them as cooked cereals. Oatmeal is prepared from the whole kernel, which is cleaned, hulled, dried and then cut into a fine meal; while in the preparation of rolled oats the grains after being cleaned are steamed for some time and finally run between rollers which press them into flakes. This preliminary cooking given these cereals in the manufacturing process shortens the time necessary to thoroughly cook them in the home, and hence they are now more generally used than the old-fashioned oatmeal or cracked wheat. The wheat farinas, sold under a variety of names, the best known perhaps being "Cream of Wheat", are obtained from the first and second breaks in the manufacture of flour. Cornmeal is a native American cereal and has been popular from very early times. In the manufacture of cornmeal the germ is generally removed, since, owing to its high fat content, it tends to make the meal rancid, and the corn is then ground into a fine meal. Yellow and white cornmeals are prepared from yellow and white varieties of corn. The process of manufacturing certain corn products varies in different parts of the country. For instance, in some parts hominy is prepared by coarsely grinding the whole kernel after only the hull is removed, while in other parts the product known as hominy has the germ and bran, as well as the hull, removed before grinding. The latter method gives a fine granular meal low in protein, fat and mineral constituents.

Preparation of ready-to-eat cereals

The cooked or ready-to-eat cereals, such as "Toasted Cornflakes", "Grapenuts", "Shredded Wheat" and "Puffed Rice", are prepared in a variety of ways, some being first cooked then dried and crushed, often toasted in addition, while others are rolled or flaked and then baked. The shredded preparations are steamed, then drawn out in shreds by special machinery, deposited in layers or bundles and baked. The whole grains may be cooked under pressure so that they puff or pop up, and form such breakfast foods as "Puffed Corn", "Puffed Wheat" and "Puffed Rice". Many of the devices used in the preparation of these ready-to-eat cereals are patented, and the products sold under proprietary names which may or may not suggest how they have been treated. In some cases sugar or molasses may have been added, and this tends to improve the flavor and perhaps the color to some extent. Practically all the toasted or parched cereals are sufficiently cooked to be eaten without further cooking, and because they are thus ready-to-serve have won an assured place in the American dietary. Some breakfast cereals have had malt added during the process of manufacture. Some of these malted cereals are ready-to-eat and others require cooking. Malt is the barley allowed to germinate until the ferment diastase has developed and then it is kiln-dried.

The diastase in malt, under certain conditions, has the power of converting the starch into dextrin and maltose, which are acted upon more easily by the digestive juices than starch itself. Thus in malted preparations the labor of digestion is somewhat reduced, and this may be an advantage for those who have weak digestion.

The proportion of starch changed to the soluble form by this process varies, depending upon the length of the malting process, and therefore many of the so-called malted preparations may not be more readily digested than any of the other thoroughly cooked whole grains.

Digestibility of ready-to-eat cereals

Digestion experiments which were carried out on healthy men to determine the digestibility of ready-to-eat cereals, have shown them to be no more completely digested than the other cereals. Digestibility and ease of digestion are different, however, and it was thought that the latter might be affected by the solubility, so experiments were made to determine the amount of soluble material in the ready-to-eat cereals as compared with rolled oats or farina. It was found that when rolled oats was cooked for five hours or farina for thirty minutes, there was as much or more soluble material as in "Toasted Cornflakes", "Shredded Wheat", and similar dry cereals, and if the rolled oats was cooked for eight hours and farina two hours, considerably more soluble material was obtained. "Puffed Rice" and "Grapenuts" were the only preparations used that had a larger percentage of soluble material.

Some of the breakfast cereals have wonderful claims made for them, but is it reasonable to suppose that they could possibly have more nutriment than the grains from which they are made? "Cornflakes" are made from corn, "Puffed Rice" from rice and "Shredded Wheat" from wheat, and so these preparations could not furnish more fuel value, more or better building material, more vitamins or mineral constituents than the whole grains, and might possibly give much less owing to losses in manufacture. Therefore we may conclude that the only advantages of ready-to-eat cereals are (1) the time saved in home preparation, (2) additional palatability (although this is probably a question of the proper preparation of the whole grains), (3) increased need for mastication of these parched cereals; while the disadvantages are (1) possible loss in building material, mineral constituents and vitamins, and (2) their relatively high cost.

In conclusion, cereals and cereal products are very important as fuel foods, but no matter how complex or from what seeds they are derived, if used as the sole diet, they will never induce optimum growth. The quality of the protein is not sufficiently high, and must, therefore, be supplemented by foods, such as milk and milk products, eggs, fish or meat, which contain a better grade of protein. In addition, all cereals are deficient in calcium, vitamin A and vitamin C, and so the diet must provide foods which will offset these deficiencies. Cereals containing the whole kernel, however, are a rich source of iron, phosphorus and vitamin B and hence should always be included in the daily dietary.

WANDERING FIRE-MISTS

The Vast Journeyings of the Comets through Outer Emptiness, and Their Recall by Sun and Planet

VISITORS TOO SWIFT AND FINE TO BE KNOWN

THE majestic spectacle of the starry sky is too generally disregarded, but there are rare occasions when everyone is gazing heavenward. A golden shower of shooting stars attracts attention; an eclipse of the moon much more; but a notable comet has in all ages been the chief wonder of the night. Some comets are so bright as to be seen in full sunlight. Thus the famous comet discovered at Johannesburg on January 16, 1910, was a few days later clearly visible to the unaided eye, shortly after sunset. It then grew daily brighter and more impressive, and revealed a tail of enormous length, stretching upward from the horizon and slightly curved. The nucleus, a bright central condensation in the comet's head, appeared to be as brilliant as the planet Venus. This nucleus was of a dusky red color, the surrounding nebulous mass of the head being of a fainter red, and the tail yellow. The comet had two tails; for, besides the main tail, which was a bright, fan-shaped jet of light projected toward the zenith, there was also a fainter and straighter secondary tail, short and bushy, and inclined about 20 degrees to the axis of the former. The main tail, which branched into two sharply curved streamers of equal splendor, was found by measurement to have a length, on January 29, of 62,000,000 miles, and extended, at its greatest length, for a distance of 50 degrees across the sky. This was one of the few bright daylight comets that have visited us since the beginning of the nineteenth century. Those of 1843, 1847, 1853, 1861 and 1882 are also famous in astronomical annals.

The magnificent comet of 1910 appeared at a time when the attention of many observers was concentrated on the movements of Halley's comet, which revisits our skies periodically, and had already been discovered on this visit as a faint nebulous body on a photograph in September, 1909, though it did not become visible to the unaided eye until early in February, 1910. By a strange coincidence, a similar appearance of some other visitant has marked several former returns of Halley's comet. This indeed, has happened so frequently as to make the tracing of Halley's comet in old records a difficult and complicated matter. Yet the history of the visits of Halley's comet has been well made out and has exceptional interest, because it gave rise to the discovery of the true nature of cometary movements.

On the appearance, in 1682, of the comet known by his name, Halley was the first to put forward the theory of its periodic return. Up to that time it had been supposed that every visit of a comet showed a separate body, which had never before appeared in our sky and was destined never to return. But Halley observed that the orbit of this comet of 1682 coincided very nearly with the orbits of the comets of 1607 and 1531, and found also that there were records of great comets having appeared in 1456, in 1301, in 1145 and in 1066. He recognized that although the intervals of time were not exactly equal in all cases, the differences were not greater than might be accounted for by perturbations due to the influence of planets.

Starting from these records, Halley ventured on the first prediction ever made with regard to a comet. He came to the conclusion that all these apparitions were the reappearance of the same comet at intervals of 75 or 76 years, and foretold that if his deductions were correct the next return might be looked for in the early months of 1759 Before that time arrived, mathematical calculations of a much more precise nature had become possible with regard to the probable influence of planets, and Alexis Claude Clairaut was able to predict what effect Jupiter would have in retarding the arrival of the comet. He fixed on April 13 as the date when the comet would pass nearest to the sun, but was careful to say that the possible action of other more distant planets, as yet unknown to astronomy, might retard or hasten it by a month. This preceded the discovery of the three outer planets, Uranus, Neptune and Pluto.

The comet actually came to perihelion — that is, its position nearest to the sun — on March 13, 1759, thus establishing its identity with the visitants recorded in history, and proving the truth of Halley's theory of periodic comets We know therefore that the comet which was hailed as a gorgeous omen of victory for William the Conqueror, and is so depicted on the Bayeux tapestry, was Halley's comet itself, which last appeared in 1910

Since Halley's brilliant discovery, more than twenty other comets have been actually observed to return in periodic courses, Encke's comet with a period of 3 years and 4 months, having been visible on more than thirty separate returns. The periodic nature of the orbits of many other comets has been demonstrated, though their return has not been actually witnessed. But of all periodic comets, Halley's remains by far the brightest and most important.

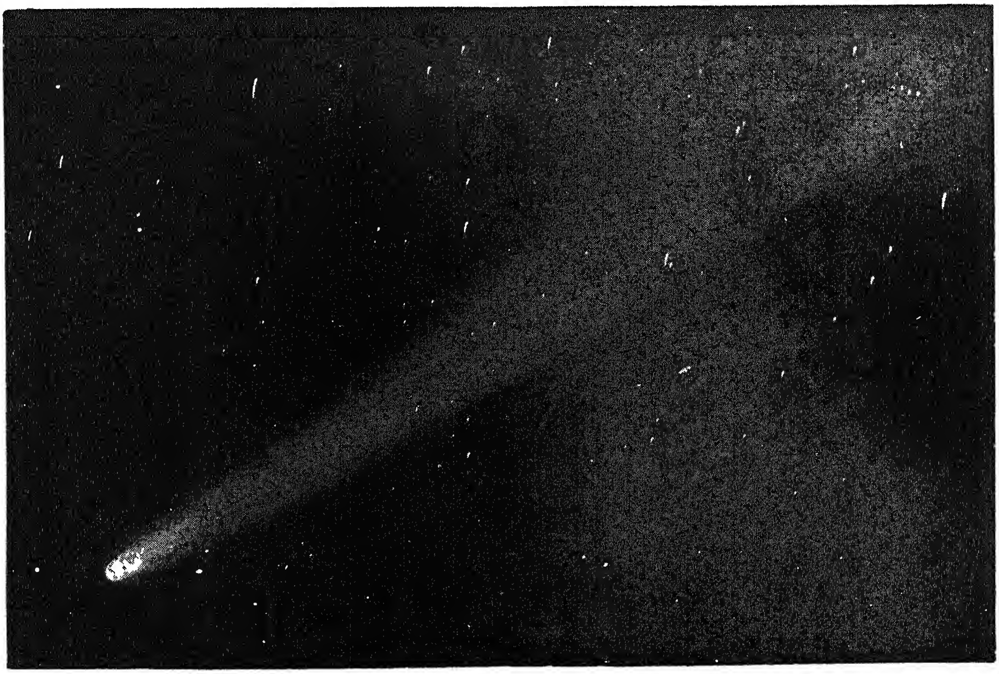
A PHOTOGRAPH OF THE COMET OF JANUARY, 1910, TAKEN AT THE LOWELL OBSERVATORY

The importance of this discovery will be understood when we realize that comets cannot be identified with certainty except by means of their orbits. There is nothing constant in a comet's appearance. The only feature of these bodies we have to

depend upon is their movement, and even that is difficult to calculate, because it is liable to all kinds of perturbations from the influence of the planets. These disturbances may be very violent, and may even result in the entire dissolution of the comet itself, or in a complete and unrecognizable transformation of its orbit.

The appearance of an individual comet is liable to extreme variations. It may appear at one time with a tail and at another time without any; it may be now very bright and again much fainter; the nucleus may be definite and brilliant like a star, or there may be no clearly defined nucleus at all. Indeed, all these and other changes may be observed in a comet during a single visit, at different stages of its progress. Its appearance, therefore, is no clue to a comet's identity; to establish this there remains only the determination of its orbit — that is to say, the path of its journey through space.

Before the discovery which was confirmed by the predicted return of Halley's comet, very various ideas had obtained with regard to the movements of comets. Aristotle, and many who followed him, regarded them merely as exhalations from the earth, which became ignited in the upper atmosphere. Some of the ancients looked upon them as living creatures, moving with self-directed motions; and from the earliest times down to a fairly recent date they were regarded as omens of disaster. It was not until the seventeenth century that the suggestion was made that certain comets moved in parabolas, but Halley was the first to conclude that there are comets which travel, like the planets, in elliptical orbits, and consequently return after regular intervals. Since then it has been proved that all comets move either in parabolic or in elliptical orbits, and therefore obey the universal law of gravitation.



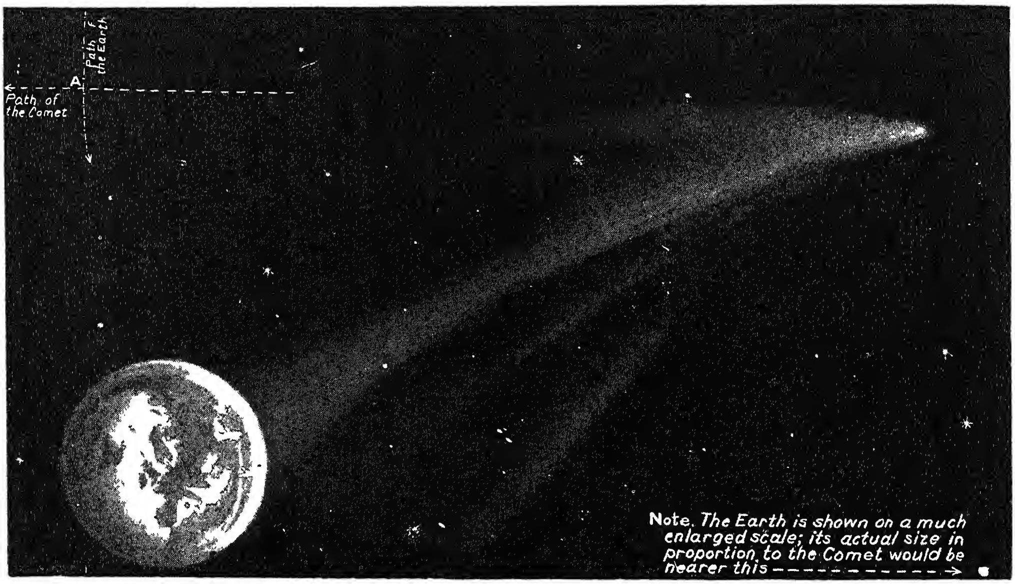
HALLEY'S COMET, PHOTOGRAPHED AT YERKES OBSERVATORY

Comets thus fall naturally into two classes: those which return, and are known as "periodic comets", and those which do not return, the former moving in an ellipse, which is a closed curve, and the latter moving in a parabola or a hyperbola, open curves of which the ends never meet. But this does not imply that all the comets that have been observed can be classified as having parabolic or ellipti-

cal orbits. W. H. Pickering made a very careful statistical study of all the well determined orbits known up to the year 1910 and found that out of 239 orbits 122 were definitely elliptical; 91 were to be classed as parabolic but among these many were very probably long ellipses, and that 62 were hyperbolic.

Inasmuch as over seven hundred comets have been catalogued, it is clear that the orbits of a large number have not been clearly determined. Moreover, the orbits of comets are at any time liable to be very considerably changed by the influence of any planet which they may approach; and nebulous form of a comet, which presents no definite point for measurement, except when the nucleus is very sharp and bright.

Since a fairly large number of known comets apparently move in parabolas or hyperbolas and consequently cannot visit our sun more than once, unless their orbits are changed by the influence of the planets, it may be asked whether comets really belong to the solar system or are simply visitors from interstellar space. Earlier astronomers inclined to the latter view, but further investigations seem to show this is a mistaken view and that even

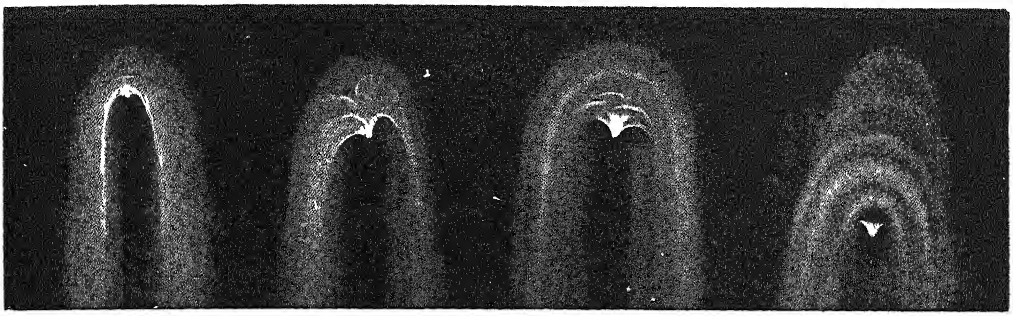


HOW OUR EARTH PASSED THROUGH THE TAIL OF HALLEY'S COMET IN 1910
The orbits crossed at A, so that the earth was only immersed in the extremely attenuated tail of the comet.

for the mass of a comet is so extremely small — that is to say, its body is so very light — that the vicinity of a planet is sufficient to alter its period by many years. By the same influence, a comet's orbit may be changed from a parabola to an ellipse, or from an ellipse to a parabola.

A comet is visible only through an extremely small section of its orbit — namely, when it is at that end of its ellipse or parabola which turns round the sun. It is therefore difficult to obtain, with accuracy, the measurements which are necessary for the determination of the orbit; and this difficulty is greatly increased by the size

the hyperbolic speed of some of the comets is due not to their having come from interstellar regions but to the perturbing influence of the planets. It is the planets, chiefly the largest of them, which determine the character of cometary orbits. Thus, all the short-period comets, which return to us at intervals of from 3 to 8 years, pass close to Jupiter's orbit at some point in their path, and appear to have been captured, in a certain sense, by this planet's powerful influence. These, which number 34 according to Pickering's investigation, are known as Jupiter's family of comets. Saturn has a similar family of two, one of them with a period of 13 years,

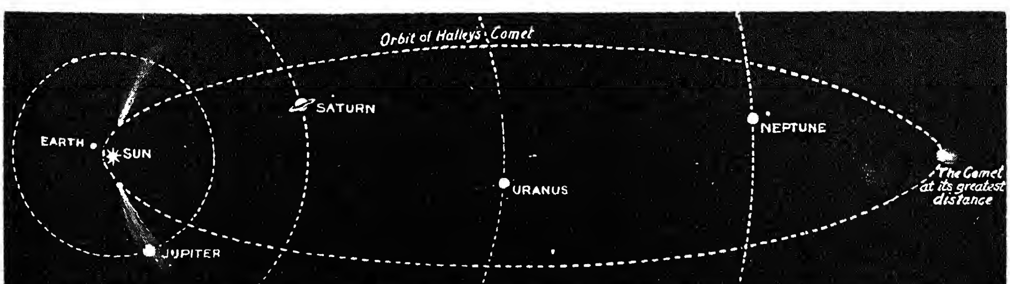


THE NUCLEI OR HEADS OF FOUR OF THE MOST FAMOUS COMETS
The comets appeared in 1858, 1861, 1874 and 1882, in the order shown.

Uranus two, Neptune six, including the three known comets with periods of from 70 to 80 years, among which is Halley's.

A comet moving in an extremely long ellipse or in a parabolic orbit and passing near a planet would have its motion either accelerated or retarded by the influence of the planet. If it were accelerated, the comet would pass out into space along a parabolic path or in a still wider curve — namely, a hyperbola; but if it were retarded its orbit would be reduced from a parabola to an ellipse, so that it would return again to the same position at regular intervals. Successive encounters with the planet might in time result in reducing the comet's orbit to the small size of those of the short-period comets, though this result would take an enormously long time to come about. If, therefore, as is probable, the comets originally belonged to the solar system, and have not come to us from without, it follows that the total number of comets is slowly decreasing; for at least occasionally some comets while under the influence of the outer planets will have their velocity accelerated and their orbits rendered hyperbolic, so that they will disappear into outer space.

There are six or more peculiar and interesting groups of comets. In each of these the comets pursue apparently the same path, but follow one another too closely to be merely successive appearances of the same comet. It is therefore suggested that the several comets of any such group have a common origin, and that at some remote period they formed, or were parts of, a single body. Some of the famous comets of the last century belong to one group of that kind, namely, the comets of 1882, 1880 and 1843, and to the same group belongs also the comet of 1668. Now, the orbit of the 1882 comet was computed to have a period of from 600 to 900 years, so that none of the other comets of this group, though pursuing the same orbit, can be regarded as former appearances of this comet of 1882. As we shall presently see, considerations with regard to the physical constitution of comets, and various changes which have been observed in them, tend to support the view that several comets moving at intervals along the same path may have originated by the disruption of a single comet. Comets move either direct — that is to say, in the direction



THE ELLIPTICAL ORBIT TRAVERSED BY HALLEY'S COMET EVERY SEVENTY-FIVE YEARS

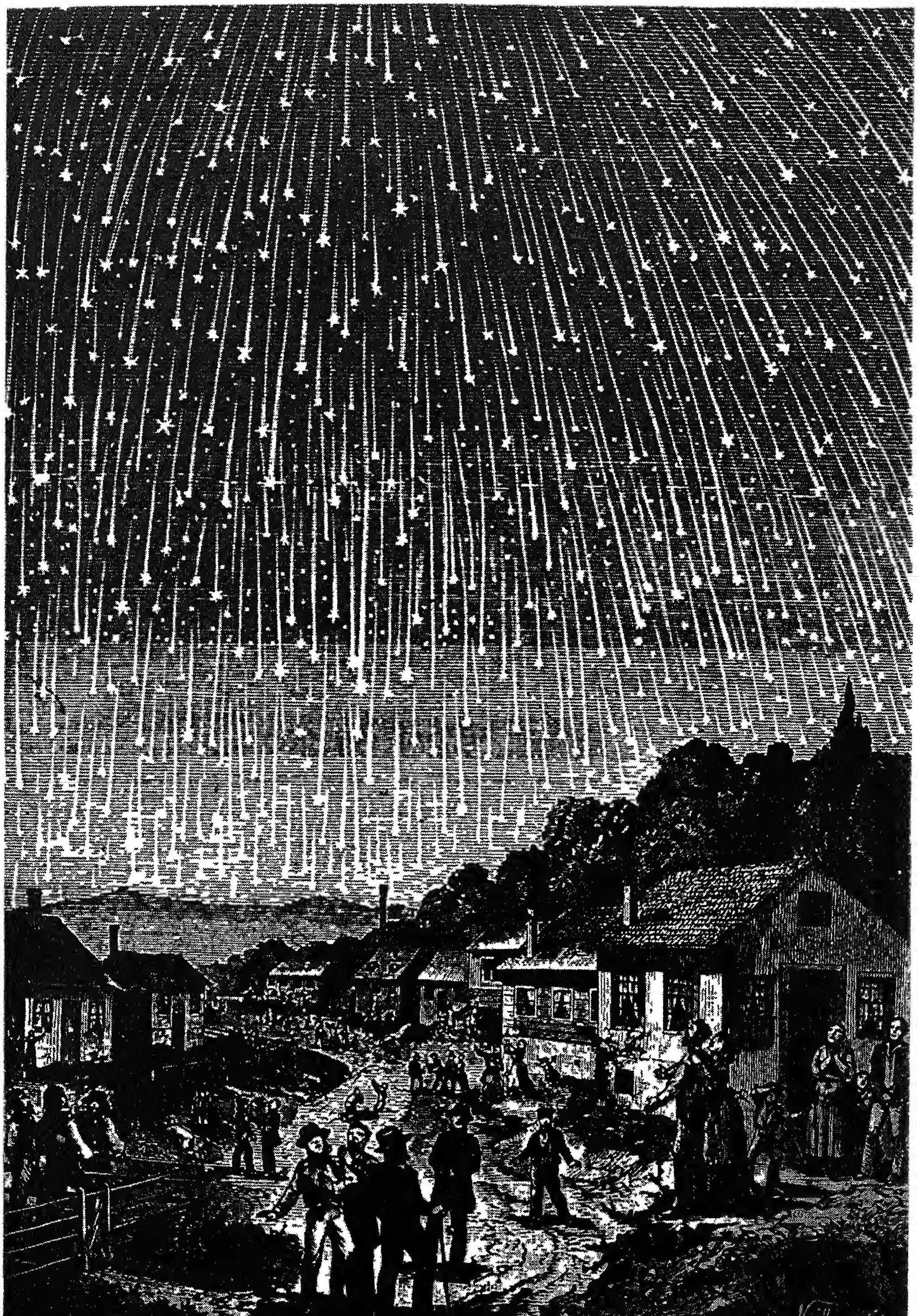
of the planets — or retrograde, and about as many travel in the one direction as in the other. But, with the exceptions of Halley's comet and the comet associated with the Leonid shooting stars, all the comets which have elliptical orbits with periods of less than one hundred years have direct and not retrograde movement

A comet — so called from a Greek word meaning "long-haired" — consists of three parts more or less distinctly marked These are the head, the nucleus and the tail. The head, or coma, is a faintly luminous nebulous mass, and is the first part to become visible as the comet approaches the sun. It has somewhat the appearance of a much blurred star. The dimensions of the coma are often enormous, varying from about 10,000 to over 1,000,000 miles in diameter. Even comets that can only be perceived through a telescope are seldom less than 40,000 miles in diameter, and are often much more, while some of the famous comets, visible to the unaided eye, have had heads larger than the sun itself. For instance, that of the comet of 1811 showed at one time a diameter of 1,200,000 miles, being nearly half as large again as the sun. On approaching the sun the head is nearly always seen to contract; part of this contraction may be merely an apparent change, due to the effect of the brightness of the sun in rendering invisible some portion of the luminous matter composing the comet, but the contraction is often too great to be so accounted for.

THE COMET OF MAY, 1901, AS SEEN IN TWILIGHT
Photographed at the Royal Observatory, Cape of Good Hope

The nucleus, as has already been said, is a mass of condensed brightness within the head. It is not always present, or, rather, it is not always visible. It varies considerably in size, the largest on record having been that of an 1845 comet, whose nucleus measured 8,000 miles in diameter In some cases the diameter is as small as 100 miles Frequent changes are observed in the nucleus as the comet progresses in its swing round the sun It becomes more definite and brighter as it approaches, and shows signs of various forms of activity. Often it throws out jets of light on the side toward the sun, or gives off concentric envelopes of light, which widen out like circles made in water by a falling stone, to lose themselves in the general nebulosity of the head Occasionally the nucleus has even been known to split up into several parts. This was notably the case in the comet of 1882, whose nucleus divided into four or five, presenting the appearance of beads strung together on a bright thread.

The tail of a comet is at once the most striking and the most puzzling part of its anatomy, and many theories have been put forward concerning it. The tail is often of enormous extent, sweeping over the heavens generally in a beautiful, plume-like curve of widening light. Those of several comets, including among recent examples the comet of 1882, have been found to exceed 100,000,000 miles in length, and at the extremity to be something like 10,000,000 miles in breadth. These are

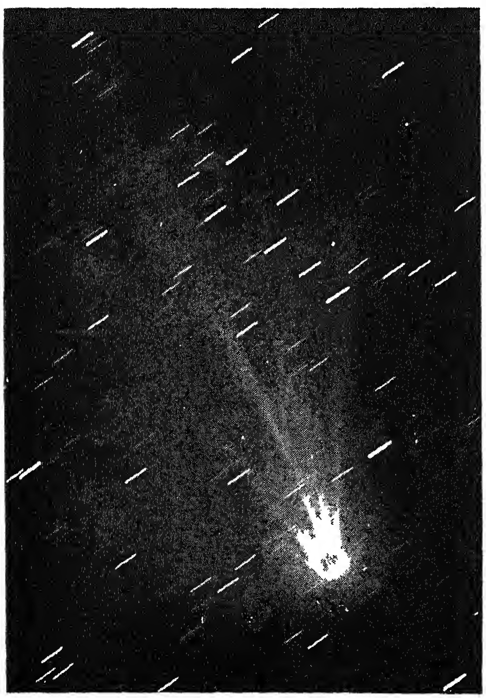


American Museum of Natural History

The great Leonid shower (of meteors) of 1833, after a contemporary drawing. The shower lasted till dawn. Leonid showers derive their name from the fact that they seem to come from the constellation Leo.

perhaps exceptional, but it is by no means unusual for a tail to attain the length of from 30,000,000 to 50,000,000 miles, and few, at their greatest length, fail to reach 10,000,000 miles. The mere volume represented by these measurements is enormous, exceeding by hundreds or thousands of times the volume of the sun.

But the mass or weight of these bodies is in comparison very small indeed. They are of such exceeding tenuity that when passing in front of the faintest star the tails of comets do not diminish the star's brightness in the slightest degree. The



THE MOREHOUSE COMET ON OCTOBER 3, 1908

head, or coma, is equally transparent, with the exception, probably, of the nucleus. Another proof of the extraordinary tenuity of comets may be found in the fact that, although comets have passed quite close to various planets, and our earth has passed right through the tail of at least one comet, these delicate glittering things have never had the slightest appreciable effect upon the solid bodies they have approached or encountered. So far as the most exact measurements and calculations can go, a comet has never pulled a planet in the least degree out of its orbit, nor has it hastened or retarded it. The effect of a planet upon a comet, on the other hand, is often sufficient to alter its orbit entirely.

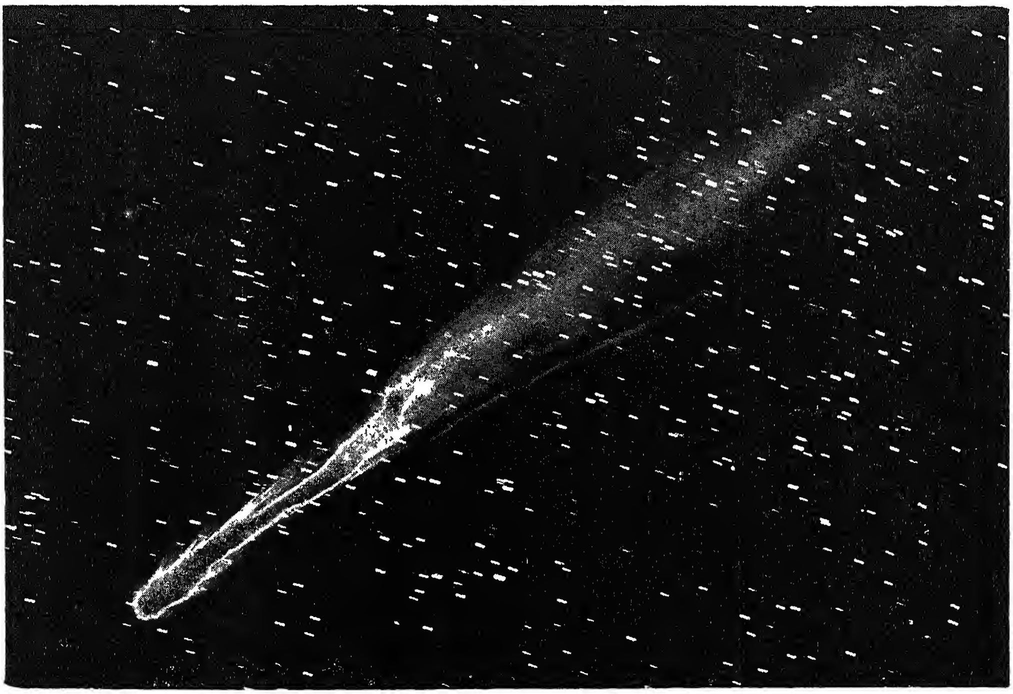
Since no effect whatever has hitherto been observed to be produced by a comet upon any other body, it is impossible even to conjecture any estimate of the smallness of its mass. We know at least that the mass of a comet must be very much less than one-100,000th part of the mass of our earth, for, otherwise, appreciable effects would have been produced by comets upon planets they have approached. It may be difficult for us, who are used to observing the motions of bodies only under the conditions of our atmosphere, to conceive how a body having such incalculably small density can move with such tremendous velocity as is shown by comets in their swiftest career; it would almost seem that these vast, filmy objects, weighing next to nothing, must be stopped at once.

But we must remember that in general, throughout interplanetary space, there is no resisting medium whatever. When the air is withdrawn from a long tube closed at both ends and a feather and a bullet are released within it, the one falls to the bottom as quickly as the other. Where there is no resistance, a comet, which is far more unsubstantial than mist, may travel as swiftly and as freely as the solid earth. The tail of a comet does not, as we might be inclined to suppose, trail after the head, as a train of smoke trails behind a locomotive. It almost always points directly away from the sun. Astronomers now believe that the radiation pressure of the sun forces material from the head away from the head to form the tail. The tail, therefore, follows the head when the comet is approaching the sun, but precedes it when the comet is receding from the sun. Yet the tail is not usually quite straight, but describes a curve, convex to the direction of the comet's motion. This, at least, is the usual curve, but there are variations; for example, the curve of the tail of the 1910 comet lay concave to the direction of motion.

There are also two other types of tail, one or other of which is not infrequently seen together with the usual great plume-shaped tail. One of these is the long, straight, ray-like tail, usually very faint; the other is the short, brush-like tail, very strongly curved, which was seen as the secondary tail in the new comet of 1910. The whole subject is still obscure, but there is little doubt that these three different types of tail consist of three different kinds of material.

It is generally believed that the tail of a comet is a hollow cone, and that it consists of solid particles, probably extremely small, each surrounded by a gaseous envelope. These particles are expelled from the nucleus, and are acted upon by some repulsive force from the sun. But besides these two repellent forces they are influenced also by the gravitative forces of the sun and of the nucleus. The effective result of all these forces, which produces the form of the tail, is due to the proportion the respective forces bear to one another; and this proportion, in its turn, depends upon the nature of the particles that form the tail.

Bredikhine, a Russian astronomer, brought forward a very ingenious theory which has thrown some light upon the perplexing question of the tails of comets. He supposed that the repellent force of the sun acts only upon the *surface* of the particles, and that its power is consequently proportional to the surface of the matter upon which it acts. The gravitative force of the sun, on the contrary, is proportional to the *mass* of the matter upon which it acts, and is quite irrespective of the extent of surface. The effective force, on this theory, would evidently depend upon the ratio the surface of the particles bears to their mass. If the particles had a large surface in proportion to their mass they would be repelled more powerfully than if they were of denser material, and so had a smaller surface in proportion to their mass. But it has been found that the molecules of hydrogen, of hydrocarbon gas and of vapor of iron bear to one another such a relation in re-



THE MOREHOUSE COMET AS IT APPEARED ON NOVEMBER 16, 1908

A comparison of this photograph, taken by Barnard at the Yerkes Observatory, and that on the opposite page, taken at the Royal Observatory, Greenwich, shows the alteration in the form of the tail.

spect to this ratio of surface to mass as would produce the respective forms of the three types of tail. Bredikhine therefore supposes that the long, straight tails are composed of particles of hydrogen; the great, plume-shaped tails of some hydrocarbon gas, and the short, violently curved tails of iron vapor, probably with some admixture of sodium and other materials.

Spectroscopic tests have more or less supported his theory, though they are not conclusive in the matter. The spectroscope has shown the presence of hydrocarbon in some plume-shaped tails, but analysis of the light from the tail of Halley's and other recent comets has shown that hydrocarbons are only variable constituents of comets, because the characteristic band of hydrocarbon gas is only an occasional feature of their spectra. The spectrum of the tail has been reproduced in that of carbon monoxide at very low pressure, while the same gas at a higher density gives a spectrum very similar to that of the heads of comets. A great deal of thought has been given to the question of the nature of that repellent force from the sun which is chiefly responsible for the form and movements of a comet's tail, but beyond the fact that it is due to some form of electrical or light energy there is little agreement on the subject.

The belief that the tail consists of matter ejected by the nucleus is supported by many observations of the activity displayed by the nucleus under the influence of the sun. This activity is greatest when the tail is being most highly developed. The matter thus thrown off by the comet to form the tail, must be eventually lost, leading to the gradual diminution of the comet, and perhaps at last to its total disappearance.

The source of the light of comets has been much discussed. Do they shine by some intrinsic light, or by reflected sunlight only? The answer is that while the comet's light does depend, in some degree, upon the sun, it is not merely reflected sunlight. Two facts prove the dependence on the sun for light. In the first place, the light which we receive from the comet is partially polarized, showing that it is, in part, reflected light In the second place, the comet diminishes in brightness as it recedes from the sun, whereas if it shone only by its own light it would grow smaller as it recedes, but would not diminish in brightness.

On the other hand, the comet's light is partially generated by itself. Spectroscopic examination proves that it is not merely reflected light. But the same fact is shown also much more clearly by the capricious changes which take place in its brilliancy, quite independently of its position in relation to the sun A comet is sometimes seen to flash out with seven or eight times its normal splendor, and then after some hours to return to its normal brightness, or perhaps below it. These sudden variations, for which no external cause can be traced, reveal the presence of some inherent light, produced from the materials of the comet under the influence of the sun.

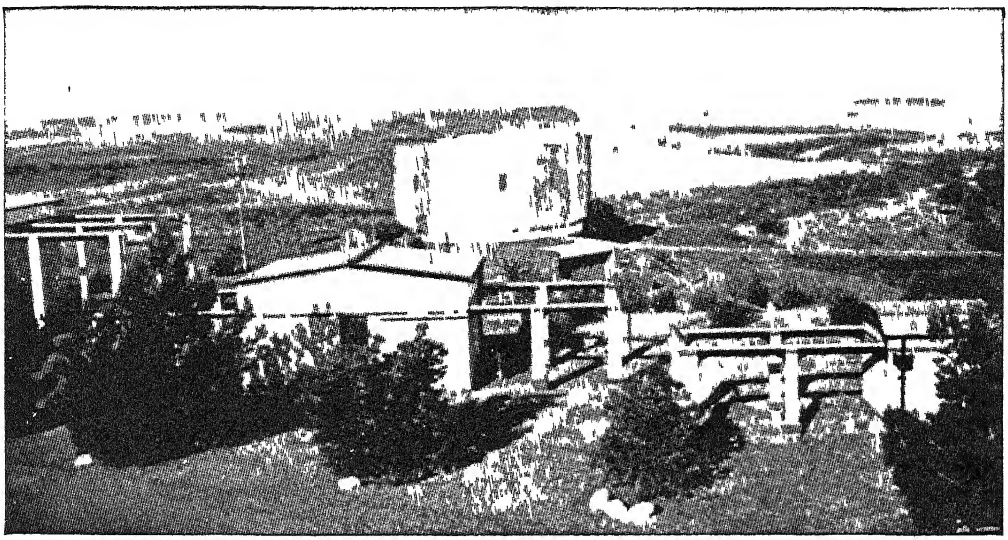
Little is known, after all, with regard to the constitution of comets. But the discovery in recent years of a very close relationship between comets and swarms of meteors goes far to support the conclusion, already adopted by many astronomers, that a comet is an enormous collection of small, solid particles, probably quite minute in size, separated widely from one another, and each surrounded by a gaseous light-producing envelope.

The most striking evidence in support of this relation between comets and meteors is the history of Biela's comet. This was a very small comet, visible only with the aid of a telescope, having a short period of about 6½ years, and was first observed in 1826 It was again seen in 1832, but was not seen on its return in 1839, owing to its unfavorable position in the sky. In 1846 it presented at first the ordinary appearance, but on December 19 it was seen to be somewhat pear-shaped, and by the 29th of the same month it had divided into two separate comets. For four months or longer the two companions were observed to travel side by side, at a distance of about 160,000 miles from one another, each having a bright and

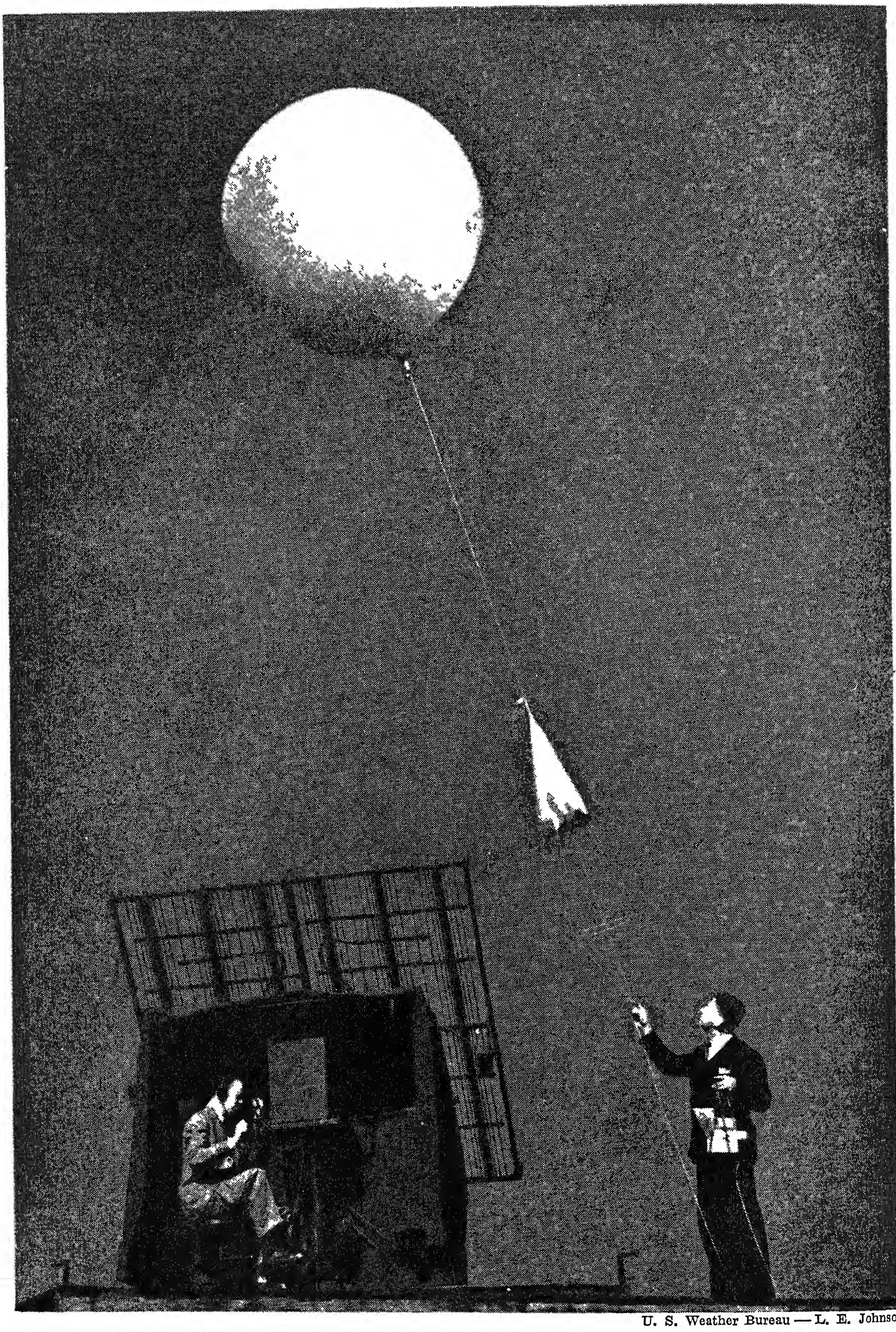
very active nucleus. There appeared to be no attraction between the two, nor any perturbing action of either upon the other, but it was noticed that when one grew brighter the other became fainter, in a curiously alternating manner For part of the time an arc of light connected them.

In 1852, the date of the next return, both comets were seen at a distance apart of about 1,500,000 miles Neither of them has since then been seen, although if they had duly returned they must have been easily observed on several visits On November 27, 1872, as the earth was passing across the path of this comet, it came into a remarkable meteor shower; and on crossing the same path again in November, 1886, a similar shower was encountered. There can be no doubt that these meteors bear some relation to the lost Biela's comet; and the simplest explanation seems to be that they are actually the disintegrated particles of the comet itself

The most striking comet of recent years was the great comet of 1882, which showed many curious and unusual features, and was, besides, of exceptional beauty and brilliance. Its light was so powerful that it was clearly visible in broad daylight, even when quite close to the sun. It remained visible from September, 1882, to March, 1883, and was seen with the telescope to a distance of more than 470,000,000 miles from the earth, so that astronomers were able to determine its orbit more accurately than usual. It moved in a very elongated ellipse, with a period of about 750 years. The nucleus was particularly interesting. At first almost round in form, it became elongated until it had assumed the shape of a long streak with several bead-like enlargements upon it, one of the beads being 5000 miles in diameter, and exceedingly bright The chain of beads lengthened until it extended over a distance of 100,000 miles. The tail of this comet was at one time more than 100,000,000 miles in length, and was marked by a bright streak along its central line, extending from the bright chain of the nucleus An unprecedented feature of the comet was a broad beam of faint light which enveloped the head and projected straight in front of it for several degrees. After passing around the sun it was found to have several nuclei instead of one, and a number of observers saw half a dozen or more cometary bodies accompanying the great comet at a short distance; and these are supposed to have been given off from it — a conclusion which appears to be supported by the history of Biela's comet.



BOYDEN STATION, HARVARD OBSERVATORY, NEAR BLOEMFONTEIN, SOUTH AFRICA


U. S. Weather Bureau — L. E. Johnson

Observer about to release a balloon carrying a radiosonde, which records air pressure, temperature and humidity. The other observer will follow the balloon by radar in order to study the air currents.

THE WEATHER MYSTERY

Dependence of Climate on Balance Between Power of the Sun and the Shelter of the Atmosphere

AT THE COOLING POINT IN THE EARTH'S LIFE

ETYMOLOGICALLY the word "climate" implies inclination, for man long ago recognized the meteorological importance of the inclination of the sun, but the term has now a much more comprehensive significance. Wind, rain, dust, humidity and all meteorological factors relevant to man's comfort or health, are included in the conception Humboldt defined climate as "all the changes in the atmosphere which sensibly affect one's physical condition", and Hann as "the sum total of the meteorological phenomena that characterize the average condition of the atmosphere at any one place on the earth's surface". It is, in fact, the *tout ensemble* of meteorological conditions considered from the double standpoint of geography and physiology. But a distinction must be drawn between weather and climate; the daily meteorological mean with respect to temperature, humidity, etc., of the atmosphere we must regard as weather, reserving the term "climate" for the seasonal or annual mean. We talk of bad weather if it rains from morning to night, and of good weather if there has been no rain for a week; we talk of a good climate when in any place all meteorological phenomena conspire on the average for man's comfort and health; and we talk of a bad climate when on the average they conspire against it.

The mainspring of the climate is the mutual relationship between earth and sun. The size and shape of the earth's orbit, the rotation of the earth on its axis, the inclination of this axis to the plane of the earth's orbit about the sun, condition the climates of the world. Were the size of the orbit of the earth doubled, its climates would be completely altered. Were it halved, we could scarcely talk of climate at all The heat of the sun is at the back of all meteorological phenomena; and the amount of heat which reaches the earth, and the relative intensity of the heat experienced at different seasons and in different latitudes depend chiefly on the factors just mentioned

Life on earth, and the climates that favor life, are confined to a small portion of the total thermal changes that our planet has experienced. Between the heat of the sun and the absolute zero there are thousands of degrees But the limits within which life obtains are separated only about 250°. We are rather inclined to claim for the earth the whole heat of the sun, but the total heat radiated into space by the sun is terrific, and if concentrated on our globe would not merely heat the earth, but would soon change it to a mass of vapors. Were we to clothe the sun in a mantle of ice two miles thick, in two hours and a quarter it would be entirely melted. Were we to lay a column of ice two and a quarter miles in diameter between the earth and the sun and to focus upon it all the heat of the sun, in a single second it would be water, and in seven seconds more it would be water-vapor — the whole column of ice, 93,000,000 miles long, would be gone in a few seconds. We do not need all this heat — it would be fatal to life; and of the total radiant energy of the sun the earth receives less than one-2,000,000,000th part — just the minute fraction necessary to insure a climate favorable to life.

Let us look now at the climatic significance of the orbit of the earth. The orbit is not an exact circle; it is what is known as an ellipse; it is a circle flattened so that it has a longest diameter and a shortest diameter at right angles to each other, which divide it into equal parts. This ellipse is very nearly an exact circle, the long diameter being only .014 per cent longer than the short diameter. Such a small departure from a true circle is this that "if a circle three inches in diameter were drawn with a very sharp pencil, making a line one-5000th of an inch thick, it would represent the orbit correctly, the difference between the ellipse and the circle being concealed by the thickness of the line".

The orbit is not quite fixed; it varies in rhythmic fashion. For about two hundred and fifty thousand years it becomes gradually more and more circular, and then for two hundred and fifty thousand years it becomes gradually more and more elliptical. The sun is situated not quite at the center of the orbit, but at a point on the longest diameter about 1,550,000 miles from its middle; and as the orbit approximates a perfect circle, the sun approximates a central position; and as the orbit becomes more elliptical, the sun becomes more eccentric. The eccentricity of the sun on the long diameter of the ellipse brings it nearer one end of the ellipse: and as the earth crosses the long diameter at this end, it is nearer the sun than in any other point of its orbit, while, as it crosses the long diameter at the opposite end, it is further away. The point of the orbit where the earth is nearest the sun is known as its "perihelion", and the point where it is farthest away is known as its "aphelion". Between perihelion and aphelion the earth gradually recedes from the sun, between aphelion and perihelion it gradually approaches it. At present the earth in aphelion is 94,450,000 miles and in perihelion 91,340,000 from the sun; that is, it is 3,110,000 miles nearer the sun at its nearest than at its farthest point.


LOOKING DOWN FROM DARJEELING ON THE WARM CLOUDS THAT THE MONSOONS BRING TO INDIA

Round this elliptical orbit, alternately approaching the sun and receding from it, rushes the earth at a rate of eighteen or nineteen miles a second. Now, it might be thought that differences in the distance of the sun must mean differences in the amount of heat received by the earth, and must therefore have important climatic consequences. One might think that when the earth is in aphelion it should be much colder than when it is in perihelion, and that when there is a maximum of eccentricity there should be a maximum of difference; and, indeed, on a supposition of this sort, attempts were made to explain the glacial periods.

But, as a matter of fact, the different distances of the earth from the sun are not of great climatic importance. Winter in the northern hemisphere occurs when the earth is in perihelion and hence nearest the sun, and summer when the earth is in aphelion and furthest from the sun; and, as is well known, it is cooler on the top of high mountains than in the plains below. The factors that modify the climate and that mitigate or aggravate the heat of the sun are the atmosphere, the relative length of day and night and the greater or lesser inclination of the rays of the sun to the surface of the earth. The daily differences between the heat of noon and even surface would have twelve hours day and twelve hours night, and for any given place the sun at noon would be day after day at the same height in the sky — *e g*, at the zenith for any place situated on the equator, and 49° 15′ above the horizon at New York or any place on the same circle of latitude. Every day, to every place, the sun would supply a certain quantum of heat; and though the amount would vary greatly from place to place, it would not vary much from day to day.

The heat, we say, would vary from place to place. Why should it vary? The same sun shines upon Timbuctoo and upon Klondike — the same sun at prac-

THE WINTER COLD THAT THE MISTRAL BRINGS TO FORT NATIONAL, IN NORTHERN ALGERIA

of day and night, are of the same nature as the differences between summer and winter, and as the main differences that distinguish climates. And these daily differences are a matter of the rotation of the earth and of the angle at which the sun's rays penetrate the atmosphere and fall upon the earth at different times of day.

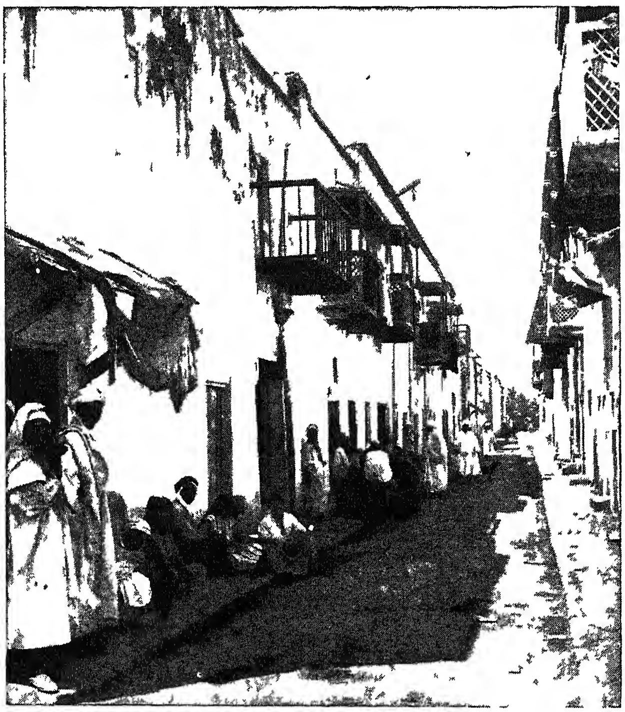
Let us look now at both these matters — at the manner of rotation of the earth and of the penetration of the atmosphere by the sun's rays. First, as to the manner of rotation of the earth. It revolves once on its own axis in about four minutes less than twenty-four hours. Were the axis of rotation perpendicular to the plane of the earth's orbit, every point on the earth's

tically the same distance. Why should the heat vary? It would vary simply because of the varying inclination of the sun's rays Every day, as we know, it is hotter when the sun is high in the sky, and cooler as the sun sinks. The same principle would be at work here The sun shining upon Timbuctoo would have a higher arch in the sky than the sun shining upon Klondike. The higher the latitude, the lower the sun's arch and the less the sun's heat, but every place would have a nearly constant temperature all the year round. Why, it may be asked, should the height of the sun in the sky, and the obliquity of the sun's rays, have such a marked effect on the temperature?

The reason is twofold First, a beam of light falling vertically is spread over a smaller surface than if it fell obliquely, and is therefore more concentrated and has more heating power One which, falling vertically, covers an area of a square inch, will cover two inches if it fall at an angle of 30°, and will have half as much heating power per inch. Second, the oblique rays have to pass through a greater thickness of atmosphere than do the vertical rays, and in their passage heat is absorbed and radiated back to space

If, then, the earth rotated on an axis perpendicular to the plane of its orbit, climate, as regards heat received from the sun, would be mainly a matter of latitude, and in each latitude there would be a constant quantum of heat received every day, barring a variation of about $\frac{1}{10}$ of one per cent due to the varying distance of the sun But the matter is not so simple as that The axis of the earth's rotation, as we know, is inclined to the plane of its orbit, and the result of this inclination is that the sun gradually in the course of the year moves northward across the celestial equator to declination 23° 27′ N., and then appears to turn and move southward across the equator to declination 23° 27′ S

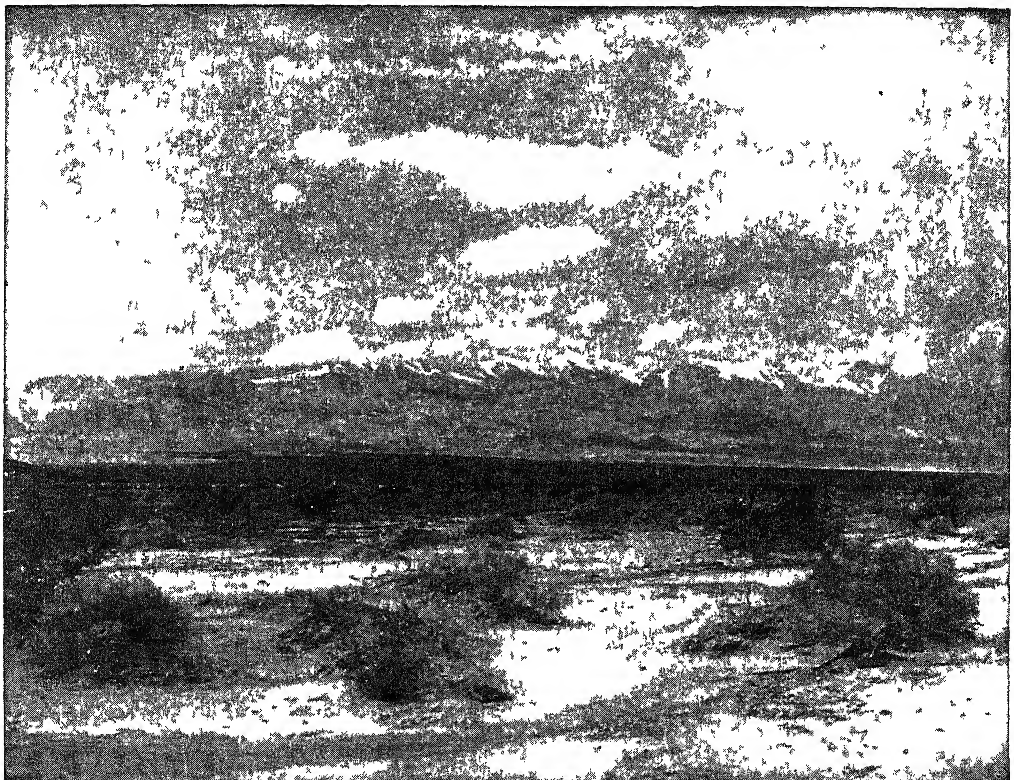
The effect of this movement is obviously to increase and decrease the height of the sun above the horizon, from day to day, in all places, in both hemispheres. From about December 21, the so-called winter solstice, to about June 20, the so-called summer solstice, the sun moves northward, and day by day the sun makes a larger, higher arch in the sky in all places in the northern hemisphere, and a lower arch in all places in the southern hemisphere from the summer solstice to the winter solstice the sun moves southward, and day by day the sun makes a higher arch in the sky in all places in the southern hemisphere, and a lower arch in all places in the northern hemisphere The result of this is, of course, that heat and daylight increase to a maximum and diminish to a minimum, from day to day, in each hemisphere alternately, and thus we have our seasons, and thus the climate in any place is not merely a matter of its latitude, but also of the varying declination from day to day and month to month of the sun itself On March 21 or within a day of that date, we have the vernal or spring equinox, and on or about September 23, the autumnal equinox; at these two dates the sun crosses the celestial equator, and then night and day are equal all the world over.



A STREET SCENE IN BISKRA, IN THE ALGERIAN SAHARA, ONE OF THE HOTTEST SPOTS IN THE TEMPERATE ZONE

The main cause, accordingly, of the varying heat of the varying seasons is not the sun's varying distance from the earth, but the height it attains above the horizon of any place at any time; and the variation in this height from day to day due to the northward and southward march of the sun gives rise to the seasons—*e g*, a winter with short days, long nights, and oblique sun-rays, and a summer with long days, short nights, and more perpendicular sun-rays.

Seeing the radical relationship between sun-heat and climate, attempts were made long ago to divide climates into zones, according to the length of the longest day. Nearly eighteen hundred years ago Claudius Ptolemy, author of the "Ptolemaic System of the Universe", divided climates into zones in which the length of the longest day increased successively by half an hour between the equator and the Arctic Circle. The zones thus delimited varied greatly in extent, for the first zone embraced $8\frac{1}{2}$ degrees of latitude and the twenty-fourth only one-20th of a degree; and further, the division did not really give much information as to the general climate of any zone, for though the heat of the sun is distributed according to length of day, many local factors alter the ultimate result. Let us look at some of these local factors.



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DEATH VALLEY, INYO COUNTY, CALIFORNIA

Combines greater heat and aridity than any other region in the world The name perpetuates the fate of a party of "forty-niners" who perished there from thirst, starvation and exposure The valley is 276 feet below sea level, 150 miles long and 15 to 20 wide The mountains are high, 10 937 feet maximum, of brilliant coloring It is the sink of the Amargosa River, which enters it from the south and disappears in the salty bottom of a former lake The rainfall is not over 4 or 5 inches in a year and the temperature registers as high as 125° F in the shade for days successively

As we have already said, the diminution of heat consequent on the obliquity of the sun's rays is due partly to the impediment offered the rays by the atmosphere and its contents. How great the impediment is is shown in a variety of interesting ways Thus the very fact that light is white and that the sky is blue is due to atmospheric interception of the sun's rays. Were the rays of the sun not sifted by the dust in the atmosphere and by air particles, the sky would be jet black The full physiological significance of the atmosphere filter we do not yet quite know, but we do know that a large percentage of the rays of the sun is obstructed by the atmosphere, and that without this obstruction the sun's rays would be intolerably powerful When the atmosphere is moist, and when clouds are formed, the hindrance to the passage of heat is much increased.

There is no doubt that the selective absorption of the rays is of great climatic importance. And in different parts of the same zone it necessarily varies to a great extent with the varying height above sea level of any district or country.

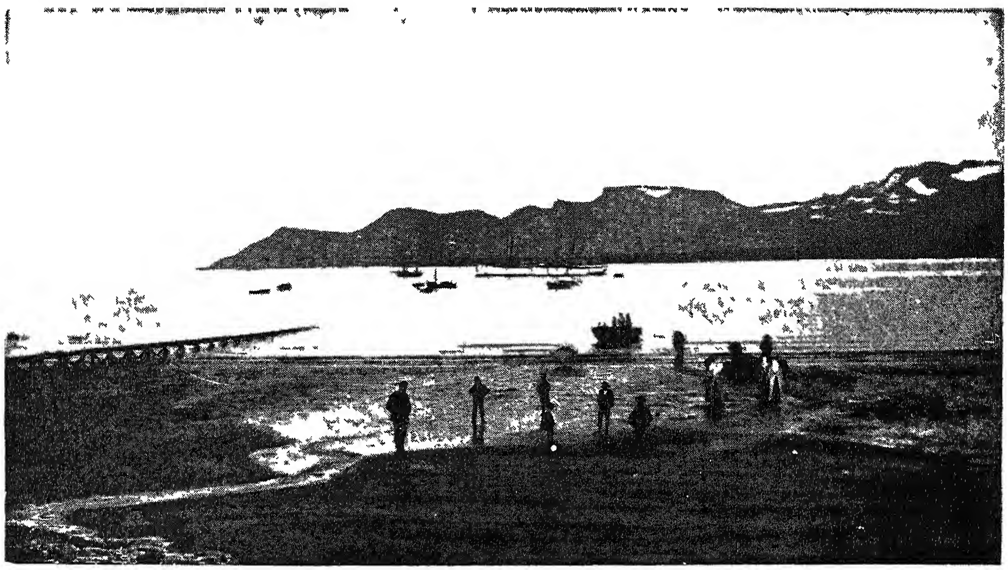
The effect on the climate of diminished absorption of the sun's rays is not at all what we at first sight would expect. Since more sun-rays pass through the air and reach the earth, it would seem at first sight that this must mean a hotter climate. As a matter of fact, it means just the reverse, as a thousand snow-clad peaks inform us. How is this? The reason is simply that in considering the average temperature of any place we have to take into account not only the heat it is given, but its retentiveness of heat. Most of the rays which are absorbed by the atmosphere are absorbed by its lower, denser layers; and all these rays, when absorbed, are transformed into heat and warm the air-molecules. The warm air-molecules of the lower atmosphere, accordingly, act as a warm blanket, and keep the earth warm during the night; whereas the higher atmosphere, being less dense, retains less heat, and is a much less efficient blanket. It is true that the sun beats with more power upon the earth when a thinner layer of atmosphere intervenes. At an elevation of 11,000 feet, water can sometimes be boiled (its temperature then being about 185° F) by putting it in a blackened bottle, and placing the bottle in the sun. But the fact is that the mountain tops are *not* blackened, and, though they may get an abundance of sunlight, they simply radiate it away again

Not only the rarity of the upper atmosphere, but also its dryness, affects radiation of heat. The moister and cloudier the atmosphere, the more does it absorb heat radiated from the earth, and radiate it back again. After a warm, sunny day the night will probably be cool if cloudless, and warm if cloudy. The rapidity, indeed, with which heat can radiate away through dry air is amazing. Dr. Robert Brown, in "Our Earth and Its Story", gives the following remarkable instances: "In the Sahara the skins of water are often frozen before daylight, though the heat of the preceding day was more than 70° above freezing-point. At Murzuk, the capital of Fezzan, in northern Africa, the thermometer will sometimes show a temperature of 133° in the shade. Yet just before daybreak, Lyon and Rohlfs tell us, it will sometimes fall, during the month of December, 7° below the freezing-point, owing to the unchecked radiation from the heated soil. Snow

THE MAIN STREET OF VERKHOYANSK, SIBERIA, NOTED FOR ITS COLD CLIMATE

also has been known to fall so heavily in the same region that in January, 1850, the flat roofs of Ghadames and Sokna, far in the desert south of Tripoli, fell in from its weight. In the Atacama Desert, the temperature of the ground is frequently 145° at midday, and even in winter the thermometer will register 98° in the shade, though four hours before it stood at 7°, this sudden change being, as in the cases mentioned, due to the rapid radiating going on in this extremely dry climate." Very different, indeed, are the climates of the Sahara and the Red Sea, yet both are in the same latitudes; and very different would be the climate of Tripoli if those parts of it which lie below sea level were flooded with the Mediterranean. At high elevations the air is necessarily dry, and its dryness, as well as its rarity, favors the radiation of heat One-half of the moisture in the air is below 6000 feet, and only one-tenth above 20,000 feet. Above a certain height, accordingly, the air is always very cold, and the temperature continues to fall as higher altitudes are reached until, at about six miles above the earth, we reach the region of constant temperature where the thermometer always registered about — 70° F.

But, besides the blanket, we must consider the baby; in other words, the soil as well as the atmosphere, since soils have widely varying capacities for heat. It is very generally considered that sandy soils are healthy, because dry, and that clayey soils are unhealthy, because damp, but, on the other hand, it must be noted that clayey soils are warmer than sandy soils The surface layer of sand is quickly heated, but sand is always mixed with considerable quantities of air, which is a very bad heat-conductor, and only the surface of the sand gets heated. The top of the sand, therefore, gets very hot, and may be heated up to 150° or 160° F., but the heat is only skin deep, so to speak, and soon radiates away Clay, on the other hand, is a compact soil and a good conductor of heat, so that the heat spreads downwards more rapidly and to a much greater depth. And so, after a hot day, clay may give off heat from its underground stores for a long time, and this is especially the case if it be water-soaked If the Sahara Desert had clayey, not sandy, soil, the days would be cooler and the nights much warmer. Again, if the ground is covered with grass, it will take in heat more slowly and give it out more slowly than if bare.



ANDO, IN THE MILD LOFOTEN ISLANDS, IN THE SAME LATITUDE AS VERKHOYANSK

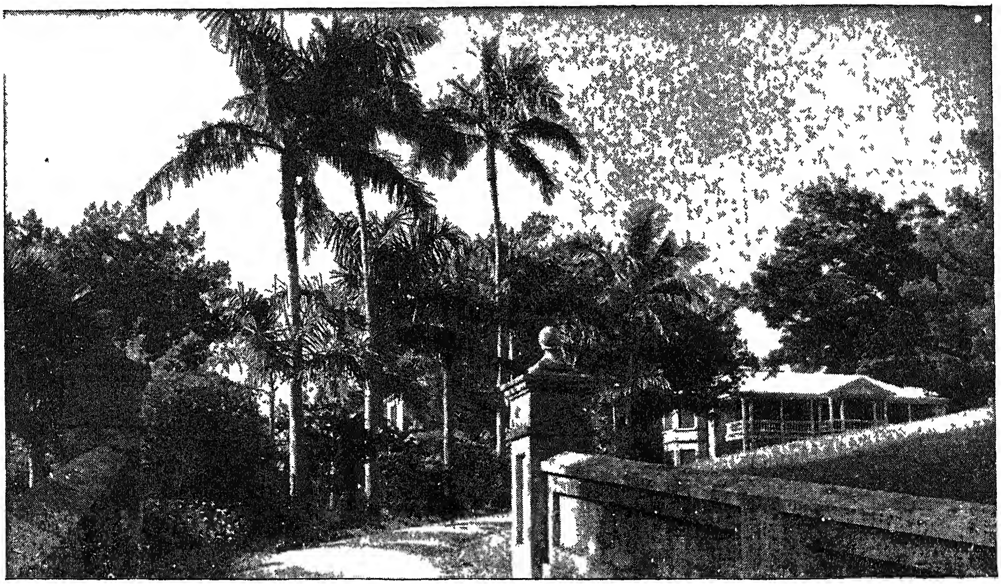
The capacity, then, of the soil for heat must be allowed for. But most important in the final average of heat is the distribution of land and water.

According to Professor Moore a given amount of heat will raise the temperature of a land surface four times as high as that of an equal water surface Land is a good absorber and a good radiator but it conducts and reflects poorly. Large land areas then retain their absorbed heat near the surface and quickly radiate it. These conditions cause, in interior land tracts, a greater daily and seasonal variation in temperature than is found in sea-coast or island climates of the same latitude. For example, the Bermuda Islands have a mean daily range of only 10° F., and an annual range of 50° F.; while Memphis, Tennessee, near the same latitude, but 700 miles from the coast, has a daily range of 17° and an annual range of 112°.

So island and sea-coast climates are usually equable climates, without great extremes of temperature.

But the sea warms not merely as a hot-bottle; it acts also as a system of hot-water heating, for its currents carry hot water and cold water all over the world. England and Norway, as we know, are warmed by sea water carried by the Gulf Stream and other great ocean currents. Alaska and the Aleutian Islands are warmed by an equatorial current, the Kuro Sivo, which reaches them via Japan. On the other hand, the coast of Chile and Peru and the west coast of Patagonia are kept cool by Humboldt's Current, which comes from the Atlantic.

More important as carriers of heat even than the currents of the sea are the winds We all know how cool breezes may temper great heat; and it is hardly possible to consider heat apart from wind The "bora", blowing down from the Julian Alps, quickly turns summer into winter; the mistral makes Algiers take to furs and fires. The foehn visits the Alpine sport-centers in mid-winter, and the snow melts like butter on a frying-pan. The sirocco withers whole vineyards in a moment. It is the monsoons that make the seasons in India — indeed, the name means season; and were India not protected from north winds by the Himalayas its climate would be very different.



IN THE BERMUDA ISLANDS WHERE THERE ARE NO GREAT EXTREMES OF TEMPERATURE

Because, then, of all these variable local factors which influence temperature, it is not possible to divide climate into zones even in respect to temperature. We can in a rough way distinguish between torrid or tropical zones, frigid or polar zones, and temperate zones, but the divisions will not be mutually exclusive, and any approximately true division lines will not be straight. Still, this rough distinction is of some value.

Extremes of temperature noted between different latitudes

We may divide off a torrid zone by two wavy lines which pass round the globe north and south of the equator through places with an average temperature of 68° F Within this torrid zone thus marked will be distributed rather irregularly most of the intolerably hot places of the world, such as Muscat, in the Persian Gulf, where the temperature may rise to 120° F and keep above 100° all night, so that "the sleepers during the night are watered, like plants, with a water-pot"; and such as Murzuk, where 133 25° F has been twice registered.

We may mark off a temperate zone south and north of the torrid zone, bounded north and south by lines passing through places with an average temperature of 32° F ; and within this zone we shall find that extremes of heat and cold are rare, though Biskra may run up to 136° F. occasionally, and some places in the United States, like Death Valley, in Southern California, may boast now and then of 120° or even 128° in the shade. North and south of the temperate zones we may place the north and south frigid zones respectively; and within these zones we shall find most of the abnormally low temperatures of the world, such as the — 73° F recorded by Nares, and the — 62° F. recorded by Parry.

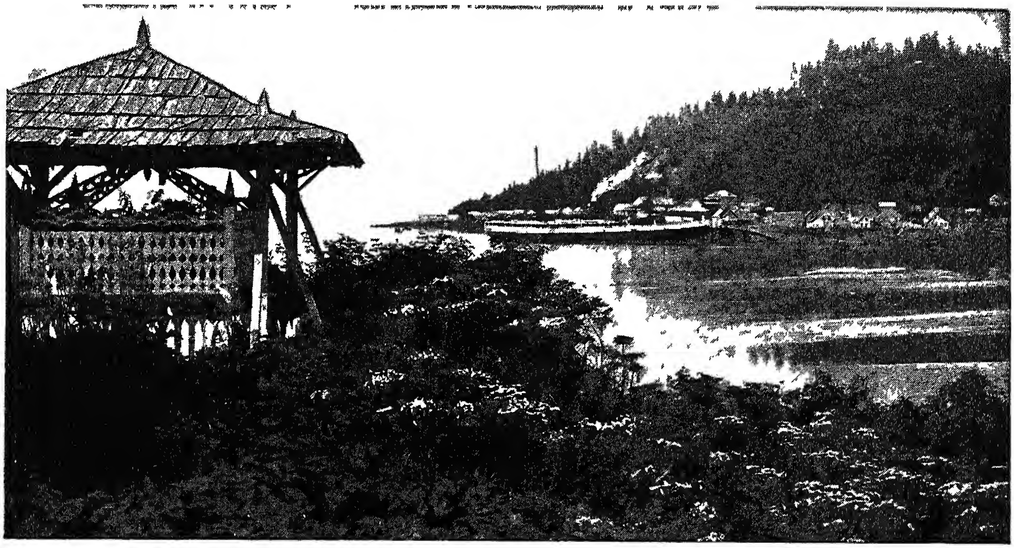
Differences of temperature noted on the same lines of latitude

Modern meteorologists have extended the principle of this division. They have drawn numerous lines round the globe through places having the same mean annual temperature — the same mean summer, mean winter, mean monthly temperature, and so on. These lines are known as "isotherms", and show the distribution of temperature in a clear, diagrammatic way Thus collated, we see that the warmest places on the globe lie on a line north of the equator, the reason for this being chiefly that there is more sea in the southern hemisphere, and that sea, as we have said, mitigates temperatures. Thus collated, we see, too, that temperatures by no means follow lines of latitude The Lofoten Islands, Norway, and Verkhoyansk, Siberia, lie in the same latitude, yet their temperatures diverge to an extraordinary degree The mean temperature of the Lofoten Islands is 40° F.; at Verkhoyansk it is 0° F The mean January temperature of Verkhoyansk is — 61° F. (and the very low temperature of — 89° F has been recorded there), the mean January temperature of the Lofoten Islands is about 32° F, a difference of 93° F Again, in July, the north of Norway, the middle of England, the middle of Siberia, and Alaska all lie on the same isotherm of 60° F ; while in January the Shetland Islands and the south of France are on the same isotherm of 40° F In January, some of our northern states are on the same isotherm as Iceland; in July, the same states are on the same isotherm as Algiers. In January, Lake Superior is on the same isotherm as Greenland; in July it is on the same isotherm as central France

The important effect on climate of moisture in the air

So far we have spoken almost entirely of temperature, but temperature is only one feature, though perhaps the most important feature, of climate. From the physiological standpoint many other features of climate must be considered Humidity, rain, wind, atmospheric pressure, have each physiological values, not only with reference to temperature, but on their own merits. Physiologically regarded, a mean annual temperature of 80° F. on the Karoo, in South Africa, and 80° F. in the Red Sea, are very different things; and likewise a mean annual temperature of 40° at Davos, Switzerland, and a mean annual temperature of 40° in Newfoundland, are very different things Conduction, convection, evaporation, radiation of heat from the body, are all largely determined by the moisture in the air, and a temperature harmless in dry air may be fatal in air saturated with moisture. Heat-apoplexy is always the result of combined heat and humidity.

All meteorological statistics admit the importance of humidity as a factor of climate, and give figures to show the relative humidity and absolute humidity of any place. The United States stretches so far north and south and possesses such a wide variation of surface that average humidity figures would be misleading. As we may boast of being one of the hottest and coldest countries in the temperate zone, so we may claim to be one of the driest and wettest. The moisture is very low in parts of Arizona and Texas but it is quite high in southern Louisiana and other Gulf localities.



THE INFLUENCE OF THE WARM KURO SIVO CURRENT — FORT WRANGELL, IN ALASKA

Wind we have already mentioned as a carrier of heat and moisture, but, physiologically speaking, it has climatic value even apart from heat and cold, simply in its essential character as moving air. It is largely because of the movement of the air that seaside places are so bracing, and largely because of the stillness of the air that muggy weather is so depressing. Quite recently, physiologists have shown that if the air be kept in motion a much larger excess of carbon dioxide can be tolerated than if the air be still.

Air-pressure, too, is of climatic importance, not only in respect to the action of the atmosphere in hindering the passage of solar rays, but in respect to its effects on the respiratory and circulatory systems Though, within considerable limits, alteration in atmospheric pressure can be easily met by the compensatory mechanisms of the body, yet health and vigor are affected by the matter of air-pressure; and the height of any place must be borne in mind in considering its climatic qualities.

All together, climate is a very complex conception, and a geographical division of climates is almost impossible, for climate is a function of geographical position only in a very broad way.

Is the climate of the earth stable, or is it subject to revolutionary changes? Within the memory of man, local physical changes have produced local climatic changes. But for the last two thousand years, at least, the general climate of the world has been what it is now; and, so far as we can see, the same climate will go on for thousands of years, unless man himself finds some way of altering it. Nevertheless, seeing that there were once jungles and forests at the poles, and that ice covered the northern United States, and seeing, too, that we do not know the cause of these great climatic variations, it were well not to be too certain that the climate of the world as we now know it may not more or less suddenly undergo great and extensive alterations.

The Twentieth Century (1895-) VII

by JUSTUS SCHIFFERES

SCIENCE AND TECHNOLOGY IN WORLD WAR II

WORLD WAR II has gone down in history as the first war in which atomic weapons — specifically, atomic bombs — were used. We shall tell you the story of the development of the atomic bomb in the next section. The bomb, which was the most effective of a tremendous host of new weapons and other military devices developed during World War II, represented the triumph of applied science, of technology, of engineering and industrial know-how. It cut the war short and saved millons of casualties, but it did not win the war. That had already been accomplished by the courage of both the military men and the civilian populations of the United Nations, coupled with the scientific and engineering genius of the United States and Great Britain.

Even more than the first World War, the second was a scientists' war. More particularly, it was a physicists' war, for many new military developments, like the atomic bomb, were based on ideas that arose from the branch of science that we call physics. World War II was also a war of metals. It has been estimated, for example, that for every American soldier in the war it required the fabrication and delivery of five tons of metal to make him an effective fighting man.

In World War II, victory fought on the side not of the strongest battalions but of the best scientists and engineers. The role of America's vast industrial plant was decisive. The United States, the greatest industrial power in the world, conducted the war as if it were a gigantic engineering operation. The bulldozer, clearing new airfields and laying roads "like toothpaste," was as potent a weapon in global war as the rocket-firing bazooka, which could stop a tank.

The best scientific brains of the warring countries were mobilized. The talents of German men of science had been diverted to military objectives after the Nazis took over the Government in 1933, six years before the outbreak of World War II. From that time until the final downfall of the Nazis in 1945, German scientists worked ceaselessly to perfect weapons of defense and offense. Their efforts bore fruit in the form of supertanks, magnetic mines, jet and rocket bombs, submarine schnörkels, and a thousand and one other grim inventions.

In the United States, scientists were organized under an official government agency, known as the Office of Scientific Research and Development (OSRD). It formed part of the War Production Board. In general, it worked with scientists through contracts made with various university and industrial laboratories. It spent half a billion dollars for research, exclusive of the money that went toward the atomic bomb, and it solved many difficult practical problems.

Other nations, too, organized their scientists for war. The British, for example, established a Scientific Advisory Committee to the British War Cabinet. Canada's National Research Council, founded in 1916 in order to increase the efficiency of scientific investigation, turned its energies to practical military research, particularly in aeronautical-engineering problems.

The plans and blueprints drawn up by scientists and engineers had to be transformed into war machines and weapons by

the resources of industry. When the United States, the greatest industrial power in the world, became the "arsenal of democracy," to quote President Franklin D. Roosevelt, the tide of war began to turn. War production became the biggest business that the United States ever engaged in; it was a $90,000,000,000-a-year business for several years. American war plants turned out vast quantities of airplanes (from Cub trainers to B-29 Superfortresses), of tanks, of armored cars and jeeps, of artillery pieces and machine guns, of rifles and carbines. To the industrial might of the United States was added that of Britain and Canada and Russia. By 1945 Allied war production had left that of the Axis nations far behind.

The success of the Allied industrial effort depended upon crucial war materials. Steel is the most basic of all such materials since it goes into practically all military vehicles and ships and weapons — warships and transports, tanks and armored cars and jeeps, guns, rifles and bazookas. The United States, the war's leading producer of steel, stepped up its production until it totaled more than 90,000,000 tons of pig iron and steel a year. New types of steel were developed, including a special family of alloys, called national-emergency steels.

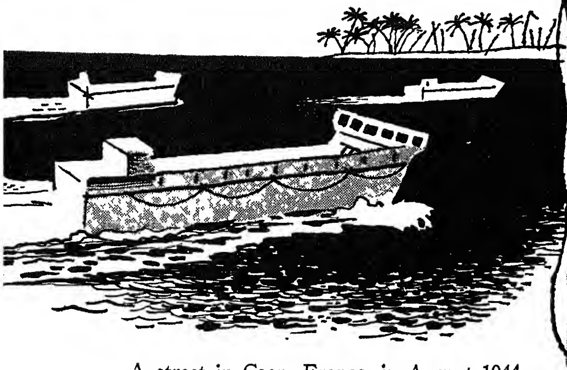
The production of the light metal aluminum also reached fantastic heights. In 1938, the world's production of aluminum was 578,600 metric tons. More than 825,000 metric tons were processed in the United States alone in the year 1943. Great amounts of electric power are required to obtain aluminum from bauxite by the electrolytic process originally developed by Hall and Héroult. The huge generating plants of the Tennessee Valley Authority supplied this power in ample measure; so did the Shipshaw hydroelectric development, which served the aluminum-processing center at Arvida, Quebec. Another light metal, magnesium, likewise came to the fore in the course of World War II.

Fashioning the sinews of war — a typical combat-tank assembly in a large American war plant.

Marmon-Herrington Co., Inc.

Canadian Army photo

Rubber was another crucial war material. As long as the Allies held Malaya and Indonesia, there were ample supplies of natural rubber. But after the Japanese overran these areas in the early months of 1942, the Allies were cut off from the bulk of their natural rubber supply. Fortunately German and American chemists had developed not less than five serviceable synthetic rubbers by the beginning of World War II: neoprene, Thiokol, Butyl, buna and buna S. They could be manufactured out of such readily available materials as petroleum, coal, salt, limestone and water. The United States began to expand its manufacture of synthetic rubber, particularly of buna S. Months before the end of the war, America was producing an adequate supply for its allies and for itself.



A street in Caen, France, in August 1944.

Another important war material was petroleum. The Allies, fortunately, had access to vast oil fields throughout the war; the chief problem was that of transporting oil to the fighting fronts. There was generally enough oil for the fighting men; civilian supplies, however, had to be curtailed considerably.

Japan faced critical shortages in petroleum until she conquered Indonesia and Burma, rich in oil. After that there were no more shortages until the Allies cut the Japanese supply lines. Germany had inadequate supplies of petroleum; but she made up for this lack by the large-scale production of synthetic oils from coal and lignite. It is estimated that from one-third to one-half of all of Germany's petroleum needs were supplied by synthetic oils in World War II.

Some of the weapons that had first come into prominence in World War I became even more important in World War II. The airplane became a major factor in the fighting. The astonishing successes won by Germany in the early years of the war were due as much to her vastly superior air force as to her concentration of tanks. The German air bombardment of Britain took a terrible toll, and only the heroic efforts of the Royal Air Force saved the day.

Later in the war, massive Allied raids on the industrial centers of Germany (as well as those of her satellites and captive nations) contributed powerfully to the collapse of the Nazis. Allied mastery of the air was so complete in the later stages of the war that German planes were almost entirely absent from the landing beaches when the Allies invaded Normandy. Air bombardment also played a prominent part in Japan's downfall. Allied bombers sank the surface ships of the Japanese and devastated their cities with high explosives and fire bombs.

Tanks also played a major role in World War II. In the first years of the war, the Germans won amazingly complete and rapid victories with their massed tanks, supported by planes and infantry. They called this new kind of warfare, appropriately enough, the blitzkrieg, or lightning war. Various antitank weapons were developed and used effectively; yet, till the very end, the tank remained an important factor in land fighting.

German U-boats were even more active in the second World War than in the first, sinking the staggering total of 23,351,000 tons of allied shipping. Allied submarines were also busy. Those of the United States did yeoman service in helping to defeat Japan. American submarines sank over 1,100 major Japanese vessels, including about 90 warships.

An important development in submarine design — the schnorkel — was contributed by the Germans. The schnörkel, a tube that houses intake and exhaust pipes, can be extended above the surface of the water. With this device, a submarine can be run by its diesel engines while under water instead of by storage batteries. This increases underwater speed; furthermore, the submarine can remain submerged for weeks at a time. The development of the schnörkel has made the submarine more redoubtable than ever.

Both the Allies and their foes had ample supplies of poison gases, but neither side used this deadly weapon in World War II. On the other hand, flame throwers, relatively inefficient in the first World War, were exceedingly effective in the second. Utilizing gasoline in thick or jellied form, the portable flame thrower had a range of two hundred feet; when mounted on a tank, the weapon could discharge its deadly stream of flaming gas four hundred feet or more.

A number of new weapons of offense and defense were developed in World War II. First and foremost, of course, was the atomic bomb, by far the most destructive weapon that man has ever devised. We discuss the development of the atomic bomb in the section that follows.

Rockets became a deadly weapon. Rocket projectiles had been used in warfare at least as far back as the eighteenth century, but they had been abandoned in the course of the nineteenth. In World War II the Russians developed a deadly

rocket-firing gun — the Katiusha — which launched a considerable number of projectiles at one time. The American rocket-firing bazookas were exceedingly effective against tanks. Rockets fired from pursuit planes knocked down a considerable number of bombers. In a previous chapter we described the German V-2's — giant rockets used to bomb objectives miles away.

The war saw the development of numerous electronic devices, such as radar (see Index), fire-control equipment and proximity fuses. Combination land-and-sea craft (amphibians) were developed; they bore outlandish names like alligators, water buffaloes and ducks. The British perfected an ingenious portable bridge — the Bailey bridge — which could be set up in a remarkably short time by a six-man crew and which could bear the weight of the heaviest tanks. Many other ingenious devices contributed to victory.

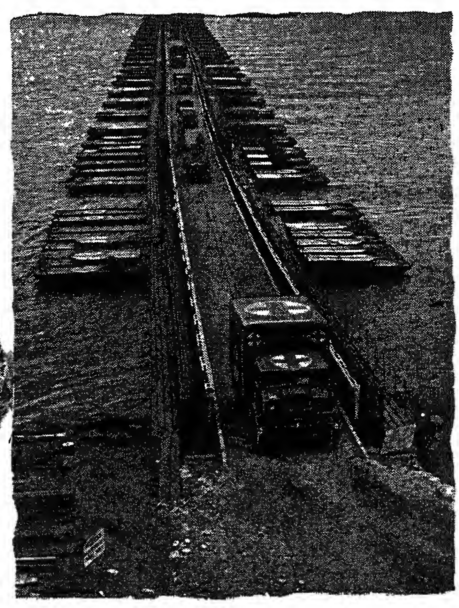
World War II took millions of lives; yet it also taught men how to save lives. DDT, the insect-killing chemical developed in the war, proved to be effective against mosquitoes, the carriers of malaria, and also against lice, which transmit typhus fever. The antibiotic penicillin and the antimalarial quinacrine (atebrin) were also developed.

Medical techniques were improved. Great advances were made in the use of blood plasma and whole blood to control shock, in front-line surgery, in mass inoculation, in the use of airplane ambulances, in aviation medicine, in rehabilitation procedures. A striking development was narcosynthesis. In this type of medical treatment, a patient is put under the influence of narcotics; he is then made to recollect and discuss his painful memories. They are thus brought out in the open instead of being allowed to fester in the subconscious

The rocket-firing bazooka, a particularly effective antitank gun.

British Information Services

Canadian Army photo



A Bailey Bridge thrown across the Rhine River by Canadian engineers.

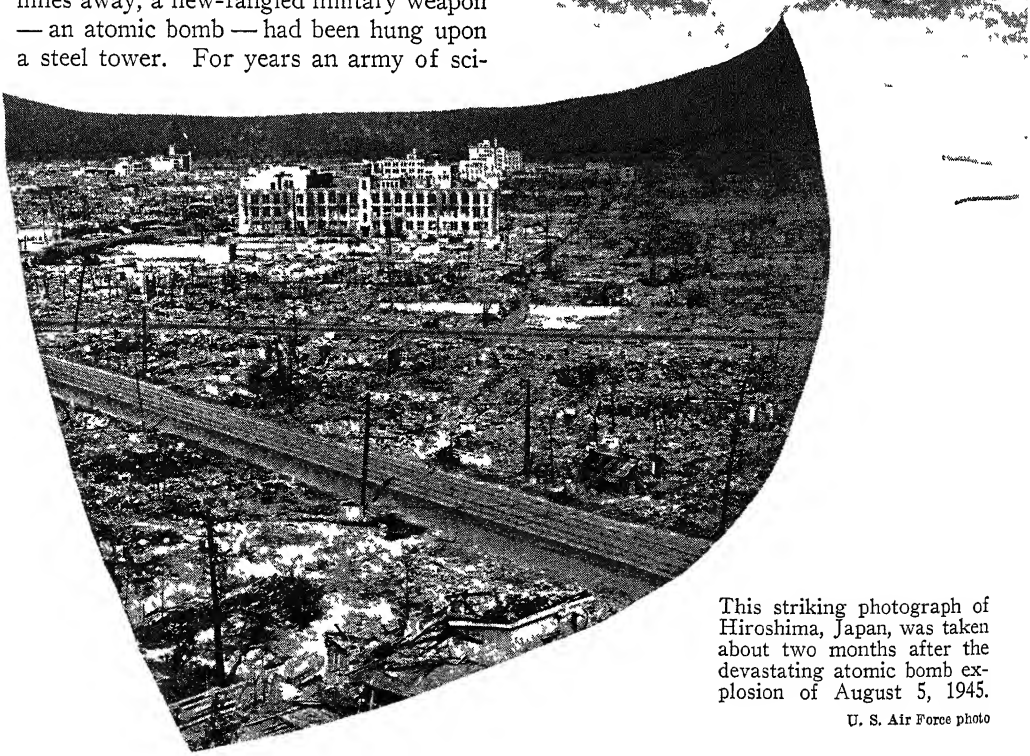
mind. Many a shell-shocked fighting man was able, through narcosynthesis, to free himself from the effects of the horrible scenes of battle that were tormenting him.

It has been claimed that the medical advances resulting from World War II have already saved more lives than the war itself took. Yet this is no excuse for war. Quite apart from the terrible loss of life and the devastation that it leaves in its wake, it has a baneful effect on science. It sacrifices basic research to applied research and exhausts the stock of new scientific ideas.

Scientists do not bring about wars, but science makes war seem more terrible. Perhaps, in years to come, that very fact may be a strong influence for peace.

THE DAWN OF THE ATOMIC AGE

Early in the morning of July 16, 1945, a small group of scientists, military men and others were breathlessly waiting in a shelter built upon the desert sands of the Alamogordo Air Base, New Mexico. Six miles away, a new-fangled military weapon — an atomic bomb — had been hung upon a steel tower. For years an army of sci-



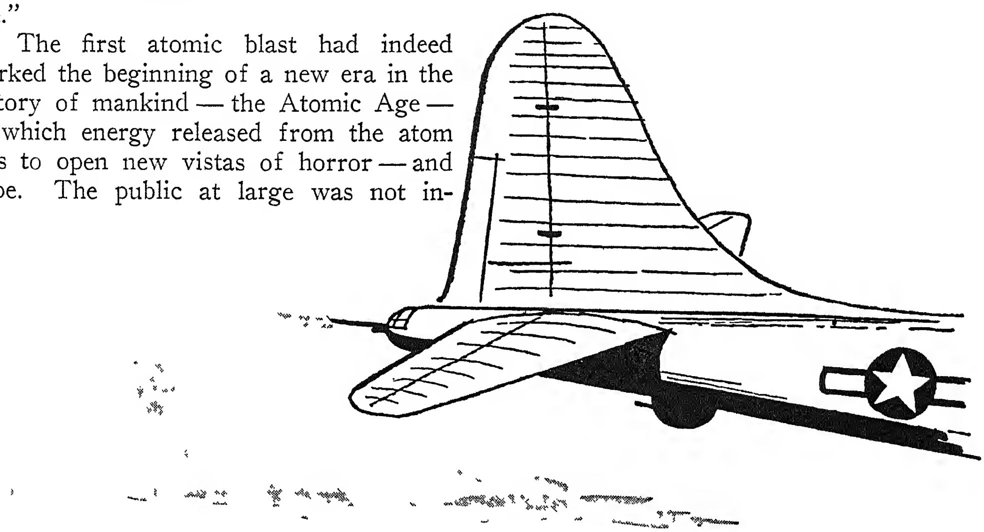
This striking photograph of Hiroshima, Japan, was taken about two months after the devastating atomic bomb explosion of August 5, 1945.

U. S. Air Force photo

entists and technicians had been working on the bomb; now the first attempt was to be made to set it off. Would it work?

The bomb was detonated at last. To quote an eyewitness, Brigadier General Thomas F. Farrell, "The whole country was lighted by a searing light many times that of the mid-day sun. It was golden, purple, violet, gray and blue . . . Thirty seconds after the explosion came the first air blast . . . to be followed immediately by a strong, sustained, awesome roar which warned of doomsday . . . Several of the observers standing back of the shelter to watch the lighting effects were knocked flat by the blast. All seemed to feel that they had been present at the birth of a new age."

The first atomic blast had indeed marked the beginning of a new era in the history of mankind — the Atomic Age — in which energy released from the atom was to open new vistas of horror — and hope. The public at large was not in-



formed of the development of an atomic bomb for several weeks. Then at 10:45 A.M. on August 6, 1945, Harry S. Truman, President of the United States, made a historic announcement:

"Sixteen hours ago an American airplane dropped one bomb on Hiroshima, an important Japanese Army base.

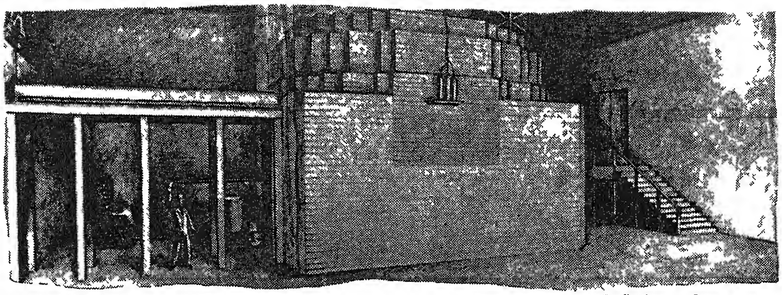
"That bomb has more power than 20,000 tons of TNT . . . It is an atomic bomb. It is a harnessing of the basic power of the universe.

"Before 1939, it was the accepted belief of scientists that it is theoretically possible to release atomic energy, but no one knew any practical method of doing it. By 1942, however, we knew that the Germans were working feverishly to find a way to add atomic energy to the other engines of war with which they hoped to enslave the world, but they failed.

"The battle of the laboratories held fatal risks for us as well as the battles of land, air and sea, and we now have won the battle of the laboratories. We have spent two billion dollars on the greatest gamble in history — and won."

The seeds of the atomic age were first sown toward the end of the nineteenth century, when the phenomenon of radioactivity was discovered. In a joint paper written in 1902, Pierre and Marie Curie noted that "each atom of a radioactive substance functions as a constant source of energy." Rutherford and Soddy wrote in 1903 that this energy comes from within the atom and that it must be "enormous compared to that rendered free in ordinary chemical change."

In 1905 Einstein announced the famous equation that was to point the way to the practical use of atomic energy. It was $E = mc^2$, in which E stands for energy, m for mass and c for the velocity of light (186,280 miles per second). This equation says in effect that matter and energy are the same thing and that one can be changed into the other. It also implies that a very



U S Army photo

The first atomic pile, shown above, was built in a squash court under the west stands of Stagg Field, at the University of Chicago. Operation of this nuclear chain reactor began on December 2, 1942; at that time the first self-sustaining chain reaction took place.

small amount of mass can be transformed into an immense amount of energy. Einstein wondered how his equation could ever be put to the test. The searing explosion set off on the sands of New Mexico was to supply the proof of its accuracy.

As we pointed out in a previous chapter, the early thirties of the present century saw the development of the cyclotron and the electrostatic generator. These machines accelerated charged particles and then sent them hurtling into atomic targets. They smashed the nuclei of atoms and in so doing released large amounts of energy. But this was not a practical method for releasing energy from the atom, since only a tiny fraction of the subatomic bullets hit their atomic targets.

The Italian physicist Enrico Fermi (born in 1901) began to employ neutrons as his subatomic bullets. Fermi decided that he would have a better chance to score hits on the nuclei of atoms if he slowed the bullets down. He succeeded in doing so by having the neutrons pass through sheets of paraffin or other carbon compounds, which came to be known as moderators. Heavy water was also used for this purpose.

The German physicists Otto Hahn and F. Strassmann used slow neutrons to bombard the heavy chemical element uranium. They were astonished to find that one of the end products of the bombardment was the element barium, which is only about three-fifths as heavy as uranium. Lise Meitner (born in 1878), a German-Jewish physicist, who had formerly worked with Hahn and who had fled from the Nazis to Copenhagen, realized the significance of this find In a letter dated January 16, 1939, and published in NATURE, an English scientific periodical, Fraulein Meitner and O. R. Frisch, a fellow refugee, wrote that the uranium nucleus, under neutron bombardment, splits into two nuclei of roughly equal size: one of these, they said, is the nucleus of the barium atom. This splitting of the nucleus was given the name of atomic fission.

Fraulein Meitner and Frisch discussed their findings with the eminent Danish physicist Niels Bohr. When he visited the United States in the early part of 1939, he gave this vital information to various American physicists. Some of them began to work on the problem of atomic fission They discovered that when a uranium atom absorbs a neutron in its nucleus, it splits into barium and krypton and something else. That something else consists of extra neutrons, which can act as atomic bullets to split more uranium atoms. This can bring about a chain reaction of fission — the splitting of one atom after another in the fraction of a second. Scientists in France and Germany also verified the freeing of neutrons in fission. It was realized that the total energy released in a chain reaction involving billions of atoms would be enormous. A bomb based on such a chain reaction would be fearfully effective.

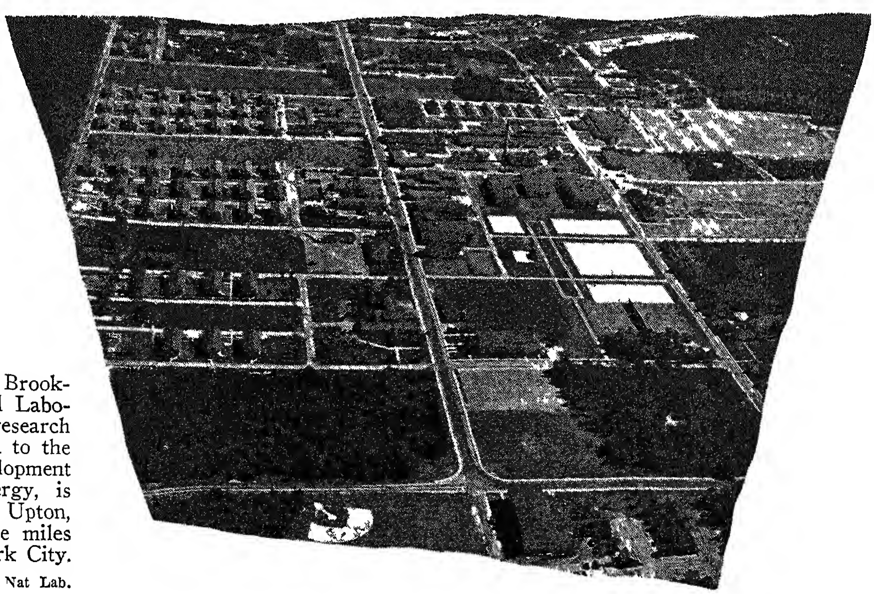
Toward the end of 1939, President Roosevelt named a commission to investigate the use of atomic energy for military purposes. In 1942, on the recommendation of the Office of Scientific Research and Development, the project was turned over to the War Department, and Major General

Leslie R. Groves was placed in charge of it. Work on the atomic bomb was now pushed feverishly, but it was all top secret; the public knew nothing of all this until President Truman's announcement of August 6, 1945. Soon afterward, Professor Henry D. Smyth, of Princeton University, published his historic report ATOMIC ENERGY FOR MILITARY PURPOSES, giving a detailed history of the development of the atomic bomb.

One of the first problems was to find out which of the several isotopes of uranium underwent fission when bombarded with slow neutrons. It turned out to be U 235 (uranium with atomic weight 235), which has 92 protons and 143 neutrons in its nucleus. Experiments in a lattice structure of uranium and graphite in the basement of Schermerhorn Hall, Columbia University, showed that when U 235 atoms fissioned, neutrons were released.

It was decided, about the end of 1942, to build a self-sustaining reaction system, in which the number of neutrons released by fission and striking atom targets would at least equal the number of neutron bullets lost by escaping through the surface of the lattice structure. A cubic lattice, consisting of uranium and uranium oxide, within a spheroid of graphite, was constructed in a squash court under the west stands of Stagg Field, at the University of Chicago. Strips of cadmium, acting as absorbers of neutrons, were inserted at intervals. On December 2, 1942, the cadmium strips were withdrawn and a self-sustaining chain reaction took place — the first that had ever been brought about. The lattice structure became known as an atomic pile, or nuclear reactor.

Scientists were now convinced that the development of an atomic bomb, based on the chain reaction involving U 235 isotopes, was entirely possible. First of all, however, it was necessary to provide enough U 235 to make a bomb. Unfortunately, only one atom in 140 in a mass of uranium is a U 235 isotope; practically all the rest of the atoms are U 238 isotopes, which cannot fission. It was necessary, therefore, to devise some method of bringing about large-scale separation of U 235 from ordinary uranium. At the same time it was decided to use plutonium as an alternative material for atomic bombs. This man-made element was derived by bombing U 238 with neutrons; when a U 238 atomic nucleus absorbs a slow neutron, it becomes U 239 and, ultimately, plutonium. (Even-



Aerial view of Brookhaven National Laboratory. This research center, devoted to the peacetime development of atomic energy, is located at Upton, about sixty-five miles from New York City.

Brookhaven Nat Lab.

tually both U 235 and plutonium were produced in adequate quantities.)

From now on the making of an atomic bomb was essentially another one of the gigantic engineering operations that were so characteristic of World War II. We have not space here to mention all the eminent scientists, engineers, military men and corporation executives who played a part in the actual manufacture of the first atomic bomb. Practically every large American manufacturing corporation contributed some of its know-how to the construction and operation of the atomic-bomb plants that were built at Oak Ridge, Tennessee, and at the Hanford Engineer Works on the Columbia River, in Washington.

The atom bombs dropped at Hiroshima and Nagasaki brought World War II to an awesome close. Since that time research in nuclear energy has continued on a vast scale in the United States, Russia, Great Britain, France, Canada and other lands. A new kind of atom bomb, the hydrogen bomb, has been developed. This weapon, many times more destructive than the uranium bomb or the plutonium bomb, is based not on fission but on fusion — the building up of light atoms to form a heavier one. In the hydrogen bomb, four atoms of hydrogen combine to form a single atom of helium, releasing energy in the process. But it takes a fission bomb to generate enough heat to set off an H-bomb.

Fortunately the story of atomic energy is not an unrelieved tale of destructiveness. Already energy derived from the atom is beginning to play a part in the peacetime activities of the world, and the possibilities in this field seem almost endless.

Some day the heat produced in the atomic pile, or nuclear reactor, will be transformed into power for doing useful work. It will drive dynamos, which will generate electricity; it will propel surface ships and submarines and flying machines. Already scientists and engineers are working on all these projects.

Hundreds of radioactive isotopes of different elements have already been produced in the atomic pile, and they have been put to good use. For one thing, we can substitute radioactive isotopes for ordinary ones that commonly take part in chemical reactions. Radioactive isotopes reveal their presence, wherever they are, because of the radiations they emit. Since we can trace these "tagged" atoms, whether in the digestive tract of an animal or in the growth process of a plant, we call them tracers.

Radioactive tracer elements have added greatly to our knowledge of photosynthesis, that mysterious process whereby the plant manufactures food in the green leaf in the presence of sunlight. In manufacturing this food, the plant uses carbon dioxide taken from the air. To study this process effectively, researchers substitute the radioactive isotope C 13 for the isotope C 12, normally found in carbon dioxide.

Tracers can be used in many other ways. They can measure accurately the wear and tear on blocks of metal. Tracers in gases can be used to study the flow of air in furnace ducts and in ventilating systems. They serve to analyze the movements of gases from smokestacks under varying conditions of wind direction, atmospheric pressure, temperature and humidity. The flow of underground water from sewage-disposal plants can be followed by adding a little radioactive salt to the water. If any of the sewage water seeps into neighboring streams or wells, tests will readily reveal the presence of this radioactive water.

Radioactive isotopes have proved very valuable in medicine. The penetration of substances from the blood into the nervous system has been studied with radioactive sodium. Radioactive iodine has been helpful in the treatment of toxic goiter. Radioactive cobalt has been used instead of radium in the treatment of certain diseases. This last development is particularly encouraging, since radium is exceedingly rare and costly.

We are now at the dawn of the atomic age. No man can tell what changes this era will bring as scientists learn more and more about the atom and the energy that is derived from its core.

SCIENCE THROUGH THE AGES is continued on page 4009.

FUNCTIONS OF THE FLOWER

Its Structure and Component Parts, and Their Relation to Each Other in Continuing the Life of the Species

THE ENDLESS MARVELS OF ADAPTATION

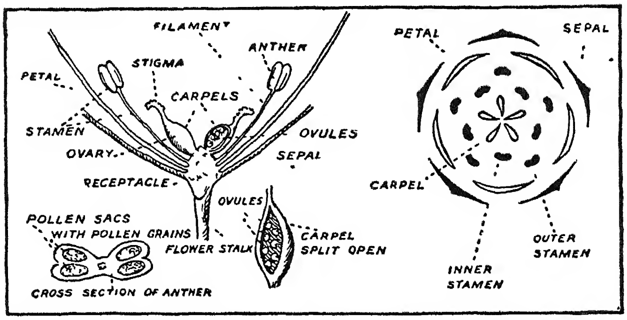
WE are now approaching the conclusion of the consideration of the life of a plant from the point of view of its individuality, though we have yet to consider one or two aspects of plants regarded as societies. So far, we have been mainly concerned in an endeavor to trace out as clearly as possible the varied aspects of the life-history of the plant, and to see what are the different factors which determine the course of the individual plant's existence and constitute its environment. Two products of an individual plant, however, still remain for our consideration, and we have left them purposely until the last because they are the final products for which the plant lives its life. We refer to the flower and the fruit. It is the former which we shall consider in this chapter.

Already we have learned a good deal about flowers in this connection. We have studied how their colors act as a means of attracting animals to them; we observed how the scent of the flowers has a somewhat similar and even more important function. As the result of these attractions we observed the manner in which an entrance is gained to the interior of a flower, and how the creatures who sought to gain that entrance are received there. Something was said as to the taking up of pollen by insects, and its deposition by them, and other means of distribution of pollen were noted in connection with wind and water. All these topics have a more or less direct bearing upon the subject of the flower, but still it remains for us to concentrate our attention upon the structure of the flower itself, its different parts and their functions.

Of all objects in natural science, probably flowers would be universally deemed the most attractive; they certainly afford to our senses the purest of gratifications. Tastes differ about almost everything else in this world, but it is safe to say that there is not a man, woman or child who is not a lover of flowers. It is not, of course, at all necessary to understand a flower in order to love it, any more than it is in the case of a human being; but flowers become of tenfold interest when one realizes all the beauty of their wonderful structure, and the marvelous adaptations for the performance of function which they exhibit.

What is the flower? Perhaps the most condensed definition, from the point of view of the botanist, would be to say that it consists of the organs of reproduction of the plant. These, however infinite in their variety of structure, coloring and arrangement they may be, possess as essential organs, in all cases, the structures termed *stamens* and *pistils*. In addition, however, most of the flowers possess *sepals* and *petals*, so that altogether there are four sets of organs. These are very often arranged in circles, and when all these sets or circles are present in any given flower it is said to be complete. The whole circle of sepals is termed the *calyx*. The petals taken altogether make the *corolla;* and calyx and corolla combined constitute the *perianth*. From the fact that the whole aim and object of the flower itself is ultimately to produce seed, and because this can only be done by the coöperation of the stamens and the pistils, these latter organs are frequently termed the essential organs of a flower.

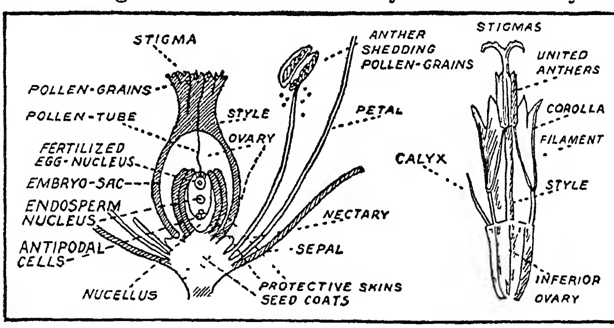
If we look at a plant with a view to observing where its flowers appear upon it, we shall find that they occupy, with great regularity, one of two positions They are either in what we have learned to call the *axil* of the leaves, or else they appear as *terminal* buds This would point to the supposition that they are of a similar nature to leaf-buds, and further observation would suggest to us that sepals much resemble leaves. In fact, in some cases it is difficult to distinguish the two. If the reader will take the trouble to examine the next example of the white water-lily he sees, he will find that in this plant there is a wonderful series of intermediate stages between petals and stamens, and many other plants show transition effects also. So that the flower is practically a greatly modified and shortened branch, a conclusion we reach, first, because the flower-buds take the same mode of origin as the leaf-buds; secondly, because many intermediate stages are found in the organs of flowers; and thirdly, for another reason not yet mentioned—namely, that in certain flowers the essential organs are found to be replaced by petals, or even green leaves.



THE PLAN OF A PATTERN FLOWER SHOWN IN LONGITUDINAL AND TRANSVERSE SECTION

Relationship between a flower and a leaf is further emphasized by the term *floral leaves*, frequently used to express all the parts of the perianth as opposed to the foliage leaves proper. To be sure, the carpels of the pistils and the filaments of the stamens described later are but modified leaves as well, though their relationship is not so obvious as in the parts of the perianth.

We understand now, therefore, that the last and uppermost or innermost leaves modified for production of the mature seeds of a plant together constitute the flower; and the axis on which this is carried is termed the flower-stalk. This stalk may be a direct continuation of the original shoot, in which case the flower is called *terminal;* but much more commonly it appears just above a leaf at one side, producing flowers which are *lateral.* Whatever the arrangement of the flowers may be on a plant, it is quite definite, and is termed an inflorescence. These various inflorescences, or arrangements of flowers on a stem, include the following kinds, amongst others: raceme, catkin, umbel, spike, capitulum or head, panicle, cyme, and so forth, all of which terms will be readily understood by a glance at the examples on page 3724.

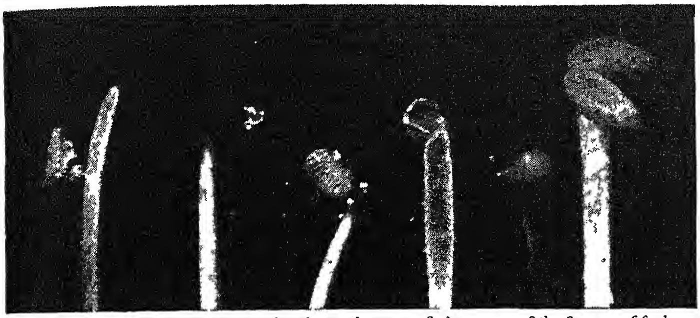


A SIMPLE FLOWER AND SINGLE FLORET OF A DANDELION IN SECTION

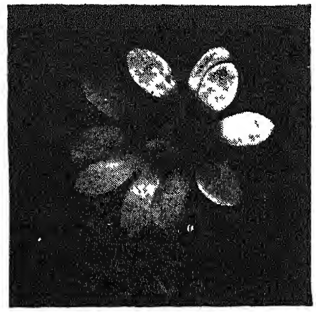
We have said that the calyx and the corolla together constitute the perianth, so that in the whole flower we may distinguish (a) perianth leaves (calyx and corolla), (b) stamens, (c) carpels.

The common arrangement of the leaves of the perianth is that of two whorls. The upper or inner of these, which may be the more delicate, is commonly distinguished by the fact that it may exhibit any and every variety of color except that they are not commonly the ordinary green of a leaf. This is the corolla. The lower or outer whorl, which quite frequently apparently

THE FERTILIZING ORGANS OF FLOWERS

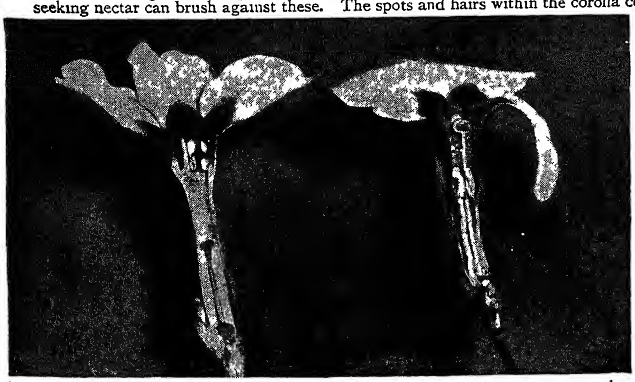


This picture, reading from left to right, shows the magnified stamens of the flowers of fuchsia, African lily, tiger lily, garden nasturtium, snapdragon, begonia and foxglove, with the anther sacs fully developed, ready to burst and shed their pollen.

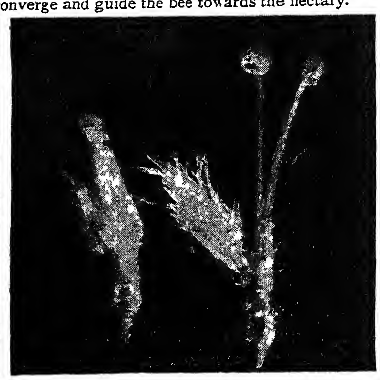


Flower of common chickweed, showing five dark sepals, five white deeply cleft petals, the stamens and three stigmas.

The mouth of a foxglove bell, opened out to show the oval stamens and the projecting stigma. Only the hairy back of a humble bee seeking nectar can brush against these. The spots and hairs within the corolla converge and guide the bee towards the nectary.

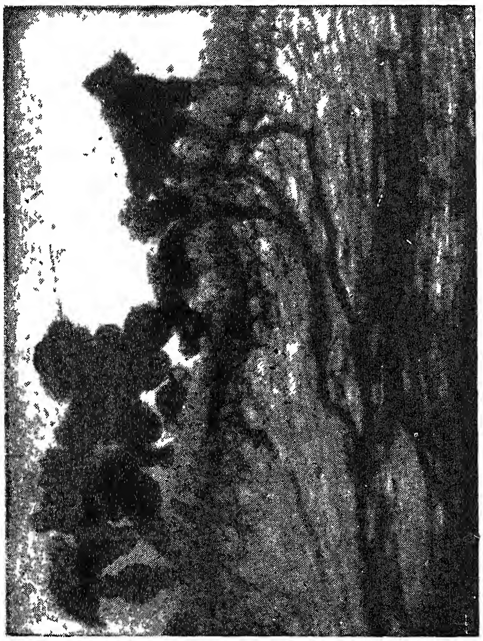


Thrum eyed and pin-eyed flowers of the primrose. The former has stamens at the mouth and the stigma midway down the tube, the latter has the stigma at mouth and stamens below. Bees can thus cross-fertilise these plants in two ways



Female and male flowers of the palm willow, the female consists of ovary scale and nectary, the male of two stamens, silky scale and nectary

consists of green leaves, is the calyx. Occasionally the two whorls look very similar. Next the stamens. These, too, are frequently arranged in whorls. Each stamen consists of two parts, an *anther* and a *filament*. The anther is of supreme importance, because it is that part of the flower in which the pollen is developed. The filament merely supports the anther, it being the sterile part of the stamen.



POLLEN TUBES PENETRATING THE STIGMA

These pollen grains on the stigma of an evening primrose are seen emitting pollen tubes, which penetrate the tissues of the stigma down to the ovary, becoming many times longer than the diameter of the pollen grain from which they arise.

Like the perianth leaves and stamens, the carpels are arranged either in whorls or spirals. In one group of the flowering plants these carpels are like scales, and have their margins quite free and ununited. But in another group the carpels are so compressed together that their margins are completely fused, and when this is the case a structure, called the *pistil*, is formed. This capsule is of very great importance, because part of it is a chamber which is really the *ovary*, and it contains the ovules, which are the rudimentary seeds. It also contains a slender stalk, or style, at the top of which there is a modification, frequently a knob, the stigma. So that the pistil consists of ovary, style and stigma (see diagram). It may be mentioned here, to clear our ideas on the subject, that eventually the ovary will become transformed into the fruit or at least a part of the fruit.

Ovule means "little egg", and was applied to the structures which develop into seeds possibly because it was thought they were similar in structure and function to the eggs of animals. If it is necessary to compare ovules with the eggs of animals, one would have to say that the ovules correspond to the animal egg plus a portion of the female parent.

It is a great deal easier, however, to compare them with the already described stamens. The ovules are the fertile part of the pistils just as the anthers are the fertile part of the stamens. The sterile part of the stamens are the filaments and the sterile part of the pistil is the carpel or carpels The anther of the stamen contains pollen and the ovule originally contains tissue, one cell of which is the egg. The coats of the ovule have an opening, the micropyle or little gate through which the sperm from the pollen passes and results in fertilization. The ovule is attached by a stalk, the funiculus, to an area on the inner surface of the carpel or pistil. This region of attachment is the placenta. The function of the ovary is probably to protect the ovules; that of the style to support the stigma, whose function is to secure pollen grains and maintain them.

Since we have learned that pollen grains are brought to the flower by such varying means and agencies as wind, insects, etc., we shall be prepared to find that the stigmas are correspondingly of great variety. In the plants which receive their pollen by the wind, the stigmas are expanded somewhat like feathers or brushes. In those which receive their pollen from visiting insects, the stigmas consist of knobs, or ridges, against which the insect knocks off its pollen in its movements on entering the flower.

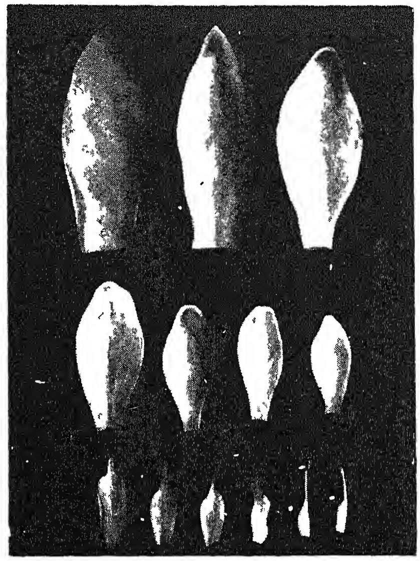
It should also be mentioned before we leave these structural details that the stamens in some cases are quite distinct from each other; in other cases they cohere by their filaments or by their anthers into one or several groups. The same is true

of the pistils, which are sometimes distinct from one another, as we see them in the buttercup, and sometimes united to form a compound pistil. In this latter case the union of the pistils results in a corresponding structure of the ovary, which is sometimes readily seen if such a cross-section be made of that organ as will show its compartments. A compound ovary may show several separate chambers, and in these chambers the ovules may be carried in a very definite line, or position. That line, we have seen, is termed the *placenta*. Where the pistil is compound there will be as many placentæ, or ovule-bearing lines, as there were carpels joined together. In this way we get different types of placentation according to the way in which the ovules are placed, and which are termed respectively parietal, central and free central.

If all the parts of the same set or circle of organs in a flower are alike, the whole flower is then said to be regular, or symmetrical. Such flowers are those whose calyx, corolla, stamens and carpels each contain the same number of parts, or a multiple of the smallest number. A flower like the stonecrop is termed symmetrical, it having five sepals, five petals, five carpels and ten stamens; whereas the rose and mignonette are irregular and unsymmetrical, because they have an indefinite number of stamens.

Lastly, in this connection, we must note the fact that there are certain flowers that, from the point of view of structure, are different in some of their parts. That is to say, in some flowers the stamens and the pistils are not found together in one, but in separate flowers, which are therefore said to be imperfect. Note carefully that this imperfection does not apply to the success with which the function of the flower is carried out, but merely means that both kinds of essential organs are not found in the same flower. For example, in the imperfect flower of the willow each flower of the catkin consists merely of a pistil, or group of stamens, plus certain sterile parts.

So much for the morphological aspect of the flower. The foregoing brief account of its structure will be sufficient for our purpose here, taken in conjunction with a careful study of the diagrams and illustrations appended. We may now turn our attention from the structure and position



TRANSITION FORMS FROM PETALS TO STAMENS OF THE WHITE WATER-LILY

of these various floral organs to the functions which are allotted to them in the life-

STAMINATE AND PISTILLATE CATKINS OF THE ALDER TREE

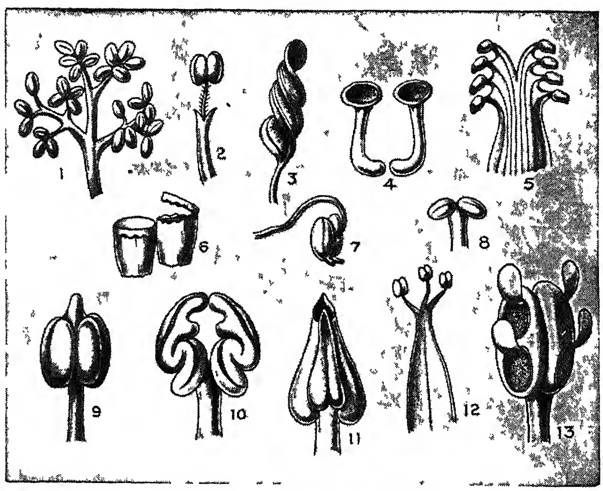
Pollen from the staminate catkins seen above is responsible for the fertilization of the tiny pistillate ones between them The latter become woody cones, like the larger ones below, which have dispersed their seeds Should these seeds alight in a stream they may spread the tree far and wide

history of the plant, reserving for a later paragraph some special remarks concerning pollen and the varying forms of its grains.

The only two structures actually indispensable for the fertilizing function of the flower are the ovules and the pollen grains. But it is quite obvious that these all-important structures must be also carefully and suitably protected in order that they may do their work. This protection must be given to them during the whole period of their development, as well as during the process of fertilizing. It is not enough that ovules and pollen grains should merely be produced. Neither is it sufficient that, having been produced, they have some measure of protection; there must also be developed adequate means for bringing them together. This is frequently attained by an exquisite adaptation in the form of the floral envelope. In fact, we find, on a careful examination of all the different parts of a complete flower, that there is a very perfect division of labor among those parts, constituting another example of that specialization of function we have studied in previous chapters in connection with different parts of the plant organization.

ARRANGEMENTS OF FLOWERS ON THE STEM, SHOWING VARIOUS FORMS OF INFLORESCENCE

1, vervain, spike; 2, cherry, simple umbel, 3, groundsel, composite heads arranged in a cyme, 4, cow-parsnip, compound umbel, 5, lilac, panicle, 6, Yucca gloriosa, panicle, 7, common marigold, composite head, 8, currant, raceme; 9, Arum maculatum, spathe and spadix, 10, walnut, catkin, 11, scarlet pimpernel, solitary



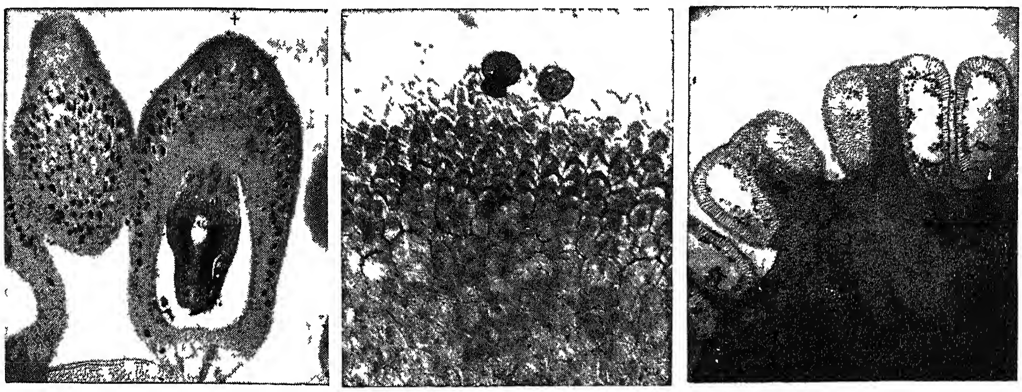
VARIOUS FORMS OF ANTHERS

1, Ricinus; 2, Aconitum napellus; 3, Erythræa centaurium, 4, Pinguicula vulgaris; 5, Polygala amara; 6, Garcinia morella; 7, Pyrola uniflora; 8, Caltha palustris, 9, Juglans regia, 10, Bryonia dioica, 11, Cyclamen europeum, 12, Corydalis capnoides, 13, Litsœa baueri

Thus we find that sometimes only one part of a flower develops ovules, or pollen — one part secures protection, one part secures fertilization. Sometimes there is a combination of duties allotted to a certain structure, as in those plants in which the carpels not only carry the ovules, but also protect them and convey the pollen to them. In others, such as the primulæ, the ovules are quite independent, so far as dissemination is concerned, being merely surrounded by ten carpels which protect them, and secure pollen, which results in their fertilization. Many plants, several already seen, produce means of attraction for insects, which collect pollen from different flowers and scatter it upon stigmas ready to receive it. But whatever the arrangements may be, and however specialized or combined the functions may appear, all are adapted towards one end—namely, that of fertilization, which is the whole object of the entire flower.

Fertilization in a plant, as in an animal, consists in the union of the essential contents of two separate cells to form a

new and distinct cell, from which latter the embryo of the new plant is destined to spring. A cell from a pollen grain unites with an egg cell at a definite point, known as the apex of the embryo sac, as shown in our diagrammatic representation of the fertilization of an ovule. The new cell which results, therefore, contains material derived from both the pollen cell and the egg cell, just as we have seen in our study of animal development that the embryo results from the union of male and female cell elements. In many plants the pollen, in order that it may succeed in its fertilizing mission, must be produced by another plant of the same species — that is to say, from a plant other than that which has produced the eggs that have to be fertilized. The pollen grains themselves — which, as we shall see later, on page 3727, are of various shapes and sorts — are launched, by one or other of the means we have already studied, on the surface of the stigma; and, having been placed, or deposited, there, they proceed to grow in the shapes of tubes, possibly taking some twenty-four hours or more before they begin to do this. The pollen tube so produced has to make its way through the *style* of the ovary, in which the ovules are lying, and this process of penetration will, of course, take a varying length of time, somewhat proportionate to the actual length of the style through which the penetration must take place. Sometimes — as in the case of the "silk" of corn — this style is several inches long, and in such a case the descent of the pollen tube through it will be a matter of several days' performance. Such a case is seen in that of the crocus; but whether the time taken be long or short, the pollen tube eventually penetrates the ovule at an opening in the apex, and, growing inwards, ultimately reaches one of the cells within. Here, therefore, takes place the union between the generative cell of the pollen tube and the egg cell of the ovule. The union produces a fertilized germ cell, which, like other cells of this character, then begin to divide again and again, and thus to grow into an embryo.



STAGES IN THE POLLINATION OF THE ARUM BERRY

The left-hand picture is a longitudinal section showing two tiny grains of pollen (enlarged in the center picture) resting on the stigma. These grains emit pollen tubes similar to those seen on page 3722, which penetrate and fertilize the egg cells of the ovule in the center The right-hand picture is a cross-section of some of the stamens, showing pollen grains developing within.

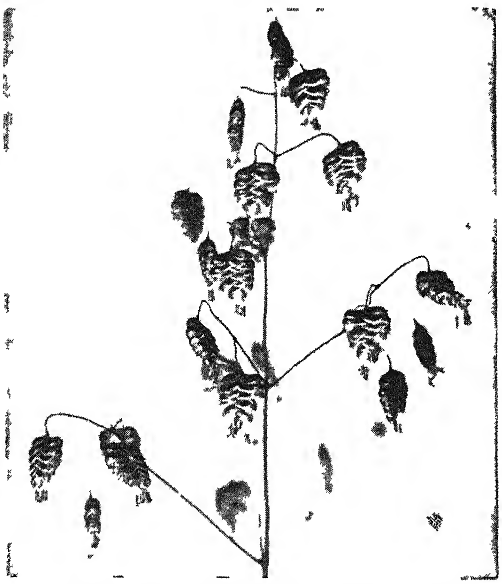
It should be noted in passing that the two terms *pollination* and *fertilization* are not necessarily synonymous. Fertilization can only occur in flowering plants after pollination, or the dusting of the stigma with pollen, has taken place. But the important point to remember is that mere pollination does not invariably mean that fertilization must ensue In spite of pollination taking place, sterility, or the absence of fruit production, may frequently occur, and this may happen for many reasons. The stigma may not be at the proper stage to receive the pollen. The pollen cells themselves may be unable to produce pollen tubes and other factors may intervene.

In order that one ovule may be fertilized, it is only necessary that one pollen tube should reach it. But, owing to the risk

that pollen runs of being lost in the process of transference from flower to flower it is obviously necessary that many more pollen grains must be produced than there are ovules requiring fertilization The excess of pollen grains produced varies very much in different plants In one variety of cereus there are no less than 250 000 pollen grains for some 30,000 ovules, or rather more than 8 to 1 In the common garden wistaria there are no less than 7000 pollen grains to every ovule, and a great many plants produce pollen grains in a proportion even many times greater than 7000 to 1 These differences obviously correspond with the manner in which the pollen is transferred from the stamens to the pistil, and the risks of loss involved in that process.

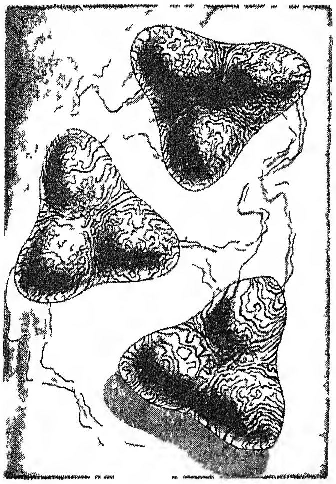
It must not be supposed, however, that any kind of pollen will fertilize all kinds of ovules We must carefully remember that in this process of fertilization in flowering plants we are dealing with living things, which are to all intents and purposes male and female, and which consist of more or less sharply defined classes, families, orders and species The possibilities of fertility and reproduction, therefore, are limited very much in the same way as they are in different species of animals if not quite so strictly One must suppose that under natural conditions especially where many flowers and plants are growing in the same neighborhood or in great clusters, the pollen of many different plants will be deposited on one stigma by one or other of the agencies concerned in pollination But unless the pollen deposited is of the character and relationship necessary, fertilization will not follow

In this connection one must not omit to mention a very curious and interesting fact with regard to pollination by insects — namely, that certain insects have been proved to show an extraordinary preference for visiting one single species of plant for quite a considerable time, especially if that plant is in the flowering stage, and in abundance in that district The advantage of this process for insect fertilization is, of course, obvious At the same time, if one carefully observes the insects among the flowers, one will soon be convinced that most of them change the flowers visited frequently Thus, "a bee which has just dusted itself with pollen in the flower of a monk's-hood will fly across to visit a bush of willow, and as it passes a plant of *Daphne Mezereum* it will suck its honey, a moment later it

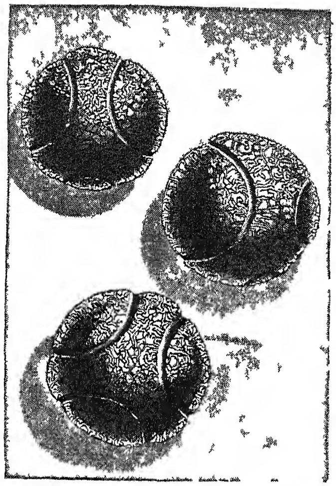


POLLEN GRAINS OF GRASSES CARRIED BY THE WIND TO THE STIGMAS OF THE FEMALE FLOWERS
The left hand picture shows a branch of quake grass whose stamens protrude through the scales of the spikelets of the flowers The pollen shaken from the stamens is blown to the stigmas of distant plants of its own species The right hand picture shows stigmas of cocksfoot grass receiving pollen grains blown to it by the wind The latter picture is highly magnified

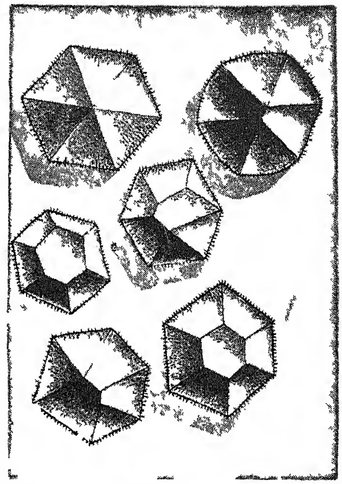
THE VARYING FORMS OF POLLEN GRAINS



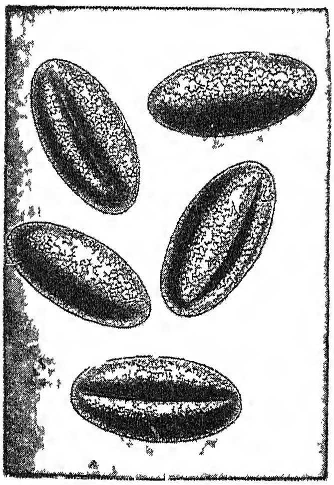
RHODODENDRON



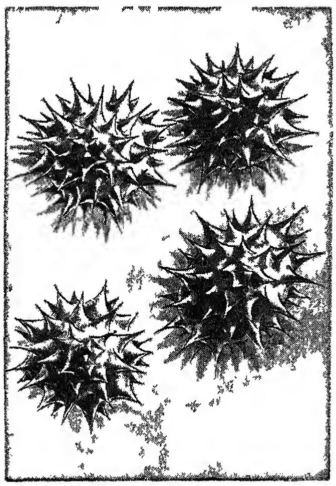
PASSIFLORA CŒRULEA



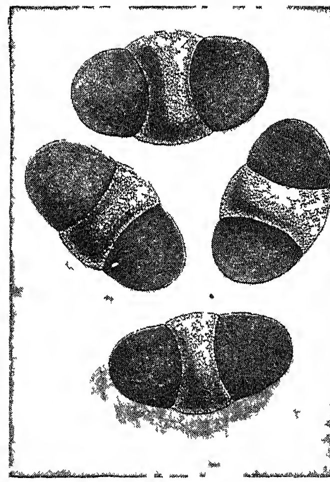
DANDELION



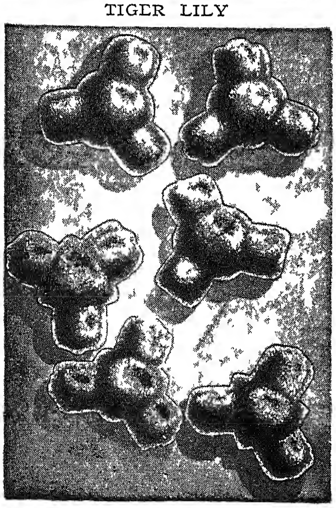
TIGER LILY



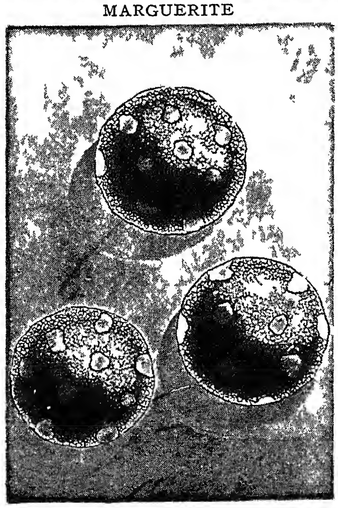
MARGUERITE



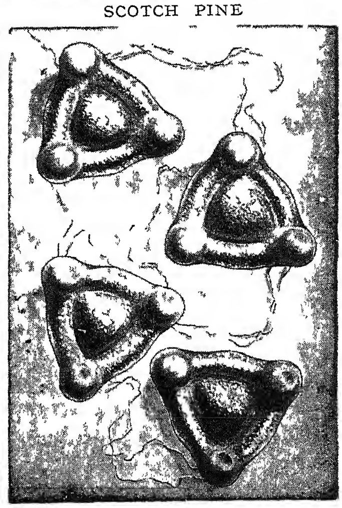
SCOTCH PINE



CLARKIA ELEGANS



PHLOX



EPILOBIUM AUGUSTIFOLIUM

will swoop down to the flowers of *Crocus* in the meadow near by, and then fly on to some violet. On the stigma of the last-mentioned plant will be found the pollen of all or several of the just-visited flowers, on the crocus that of the willow, and so on. The case is similar with wind-pollinated flowers."

In such a case the pollen of the willow does not fertilize the ovule in the crocus. All that happens to the willow pollen is that it undergoes certain physical changes which are similar if it be placed in any moist material. Complete development, however, does not occur. In other words, the tubes, if they grow, do not fertilize the eggs in the ovules. Put in another way, one may say that it is part of the function of the stigma in a flower to exercise a capacity of selection of the proper kind of pollen suitable for its own ovule fertilization. How this selection actually is brought about we do not know.

Numbers of experiments have been made upon the point, but all that we can say is that with certain pollen applied to certain stigmas fertilization does, or does not, take place; or that with such and such pollen no seed formation follows, or moderate production of seed follows or great abundance. In fact, all the observations and experiments which have been directed towards ascertaining the general laws which underlie this process have led botanists to conclude that when the pollen from one species of plant reaches, or is put upon, the stigma of another species, such pollen grains produce tubes capable of fertilizing the ovules only when the two species of plant concerned belong to the same natural family of plants. Conversely, pollination between two individuals of different natural orders of plants usually is not followed by fertilization. Finally, in this connection, if the pollen from the male flowers of a plant reaches, or be artificially placed upon, the mature stigma of the female flower of that same species, fertilization is practically certain to follow, and result in the production of fertile young. Except when the two parents are of the same species the young would not be expected to be fertile.

The pollen itself, however, as we hinted in an earlier paragraph, deserves some special mention. It is a wonderfully interesting substance, exhibiting many astonishing variations when subjected to careful examination. In many of the flowers which are not at all conspicuous to the eye the pollen is in the form of a fine, dry powder. This is the case in the family of grasses and rushes, and sedges and conifers. In the more elaborately colored flowers the pollen is frequently of a sticky nature. The grains themselves, too, differ extremely in both size and color, as well as in their consistence. Some are long and green, some long and yellow, some as broad as long. A very common shape is a somewhat oval grain rather like the shape of a grain of wheat. Our illustrations in-

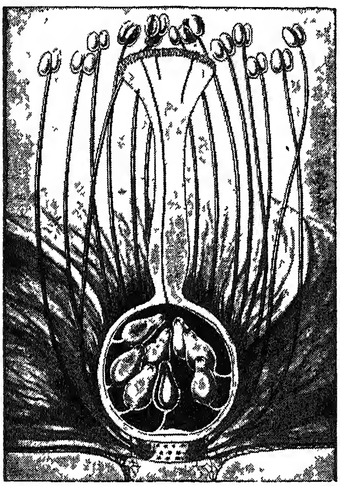
THE SELF-POLLINATION OF PYROLA UNIFLORA AND GENTIANA CLUSII

The petals have been removed at the dotted lines to show the process.

dicate the various shapes and appearances of a number of pollen grains from a number of species of plants.

Each pollen grain is chiefly made up of a cell covered by a thick outer wall and a thinner inner wall. Within these is contained the protoplasm of the cell itself, and amongst this is frequently found some grains of starch and minute oil globules On the outer surface of the grain may be seen one or two protuberances, which indicate the position where the inner coat will ultimately emerge through the outer one in the form of the pollen tube. The whole grain, in perhaps quite half of all the flowering plants, is ellipsoid in shape. Others are round, lancet-shaped, biscuit-shaped, angular, three-sided, four-sided, five-sided, six-sided, or cubical.

The surface of the pollen grain, especially in the ellipsoid and round grains, is generally grooved or marked, and the number of grooves upon the surface is found to be the same in all grains from the same species of plants. In some pollen grains there may be found very small openings in which a yellowish oil is contained. Many species of pollen have such an oily substance over their whole surface. Others stick together by means of an entirely different viscid material, such as is found in the pollen grains of the fuchsias and orchids, in which it can be drawn out into threads.



PICTURE-DIAGRAM SHOWING HOW POLLEN REACHES AN OVULE

There are other structural peculiarities and appearances in pollen grains, but the above will suffice to mention here; and the point now arises, Why all this variety in the formation of pollen grains? What is the object of all the grooves and furrows and projections, and oil and apertures and so forth? We can only answer some of these points in a sentence or two here.

When pollen is placed in water, it swells up quickly. Its inner wall must therefore be able to stretch with ease. The folds allow the fluid to pass quickly to the interior, and the grooves become inflated. The pollen grains, so thoroughly moistened, may be several times the original size. All the various inequalities and irregularities on the wall of the pollen grains enable a number of grains to cling together.

In this way an insect is able to transfer large masses of pollen at the same time. The dry pollen of the grasses and other plants — dusty pollen, as it is sometimes called — does not cohere in this way, and so cannot stick so easily. On the other hand, its consistence renders it peculiarly susceptible to the distribution by wind. The capacity of pollen grains to stick together, so that they may easily attach themselves to the hairs, legs, etc., of insects, is of very great importance. The oily and viscid coating of other pollen grains aids in a similar manner.

Lastly, we must briefly refer to self-pollination. In the simplest form, when the flower opens, the stigma is seen in front of the entrance, and already ripe, while the anthers adhere to it, but are closed. At this stage cross-pollination can be brought about. But a little later in the flowering time the anthers next to the stigma open, and the stigma itself is, of course, at once covered by pollen which is set free from them.

It must be said, however, that many cases of self-pollination are much more complicated than this. Some are brought about in pendent flowers by the pollen from the anthers falling upon the viscid stigma, as happens in the snowdrops. In many cases the stamens are particularly adapted for the process of self-pollination by the manner of their bending, or by their peculiar movements, as is seen particularly in the stamens which curve inwards. Sometimes self-pollination is brought about by a peculiar bending of the pistil, sometimes by a coiling arrangement of the stamens and the pistil, and sometimes actually by means of the corolla. This latter is seen in those flowers whose petals are cup-shaped, and in which the anthers adhere to the inner surface of the petals, coming in contact with the stigma when the corolla closes.

The fact that all these variations in flower parts and functions of parts occur, should be encouraging rather than discouraging. Only a few of the types are here presented. It is hoped that they have proven sufficiently interesting that you may wish to go to the flowers themselves for further interesting facts.

THEIR MYRIAD WINGS MAKE MERRY MUSIC ON THE MARSH

Photo Herbert K Job

BREEDING COLONY OF ROYAL TERNS ON A LOUISIANA BIRD RESERVATION

OUR COMMON BIRDS VIII

Loons, Grebes, Gulls and Terns, Herons, Geese and Ducks, Rails, Gallinules, Coots, Sandpipers and Plovers

WATER BIRDS

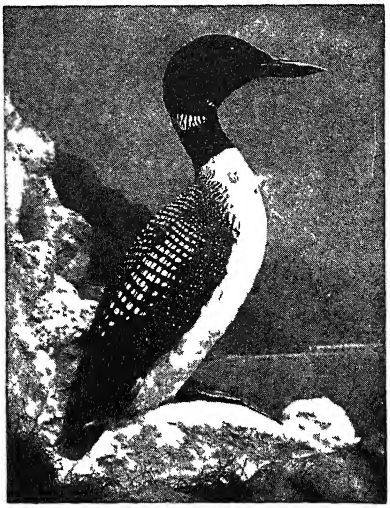
"AS crazy as a loon" is an expression that gains force when one hears the weird notes of one of these curious divers. Beginning low, the strange sonorous sound rises in pitch and increases in volume until it ends with a terrible spasmodic gasp. Heard in the dead of night when one is alone in the silent forest it has the faculty of arousing one from slumber with a stiffened scalp and strange prickly feelings in the vicinity of one's spine. Sometimes a pair of birds will hold a concert, or a single bird will locate a rocky cliff where there is a good echo and will call to himself for hours at a time. The notes are then different and resemble more the insane laugh of some escaped maniac. Those who spend their summers in Canada are familiar with the loons and their ways because one cannot camp by the lakes where they nest without being almost continually aware of their presence. Those who do not go to Canada or get into the lake country of northern New England, however, seldom see them or realize that they are present, sometimes in large numbers, on the larger bodies of water and along the sea-coast throughout the United States during the winter. For at such times they are silent and usually keep a safe distance from the shore. On their migrations over land they usually fly high and, because of their large size and long necks, they are sometimes mistaken for geese, but the flocks of loons never assume the characteristic wedge of the wild geese. Though there may be a hundred or more birds in the flock, they seem to care nothing for each other's company but fly in scattered ranks

During the winter the loons are colored much alike, being grayish above and white below, but during the summer they are quite different. There are but five species of loons in the world, confined to the northern half of the northern hemisphere, and only one of these, the common loon, is often seen. It is black above during the summer, the back spotted with white, and there is a half ring of white streaks on the neck. The underparts are white, but as it is seldom seen except on the water, when the underparts are invisible, the general impression is that of a black bird about the size of a goose but with a shorter neck and a longer bill. The bill is very strong and sharply pointed, for it is used for spearing the fish upon which the loon lives. The fish are usually small but occasionally weigh as much as a pound or even two pounds, when they are swallowed with much difficulty The fish are pursued by the loon and speared beneath the water, the strong webbed feet of the bird driving it through the water at such speed that the wings are never used unless the bird is wounded. The fish are never swallowed beneath the water, the loon always bringing them to the surface and juggling them around until it can swallow them head foremost.

The loon ordinarily lays its two olive-brown spotted eggs in a mere depression along the shore, on a hummock of mud or a muskrat house where it can quickly slip into the water and dive from sight. The young loons are covered with thick black down when hatched and almost immediately take to the water where they can swim and dive with the greatest ease.

The mysterious grebes

Closely related to the loons but differing from them in many essentials are the grebes or, as they are popularly called, "the hell-divers". There are twenty-five different kinds of grebes (family *Colymbidæ*), found all over the world, and six of them are found in North America. They are all smaller than the loons, being about the size of small ducks, which, indeed, they very much resemble. They can always be distinguished from the ducks, however, by their pointed bills, short rounded wings, and apparent absence of tails, which are represented by mere tufts of feathers. Their feet instead of being fully webbed, as in the ducks and in the loons, are lobed, appearing as though the webbing had been cut between the toes. This does not seem to hinder their swimming or diving, for they are fully the equals of their larger cousins, diving so deep and remaining under for so long that they seem never to come up. Indeed, when alarmed, they sometimes come up very quietly until just their bills show above the water, and if there is a slight ripple on the water, they are entirely invisible. This has given rise to many stories of mysterious disappearances and to such popular names as "waterwitch" and "hell-diver". They either dive head foremost with a flip of their feet, or they settle backwards so carefully as to scarcely leave a ripple on the surface. Such expert divers are they that they prefer to rely upon this method of escape rather than to fly, especially as it seems to take so much effort for them to rise. When they do take flight they ordinarily patter along the surface for some distance before they are able to get up enough speed to lift themselves from the water. Once on the wing they look a great deal like ducks, because they carry their feet straight out behind them, and these make up for the absence of a tail, which would otherwise be a conspicuous difference.



LOON

The commonest species of grebe is the pied-billed, an inconspicuous brownish little bird even when in its breeding plumage. It is found most often on reed-bordered ponds and marshy lakes where it builds its floating nest and anchors it to the reeds. The nest is but a pile of débris and looks like the little platforms that muskrats sometimes build to rest on. When the bird leaves the nest she always covers her eggs with some of the material of the nest, and as she is seldom if ever surprised on the nest, it was once thought that the pied-billed grebe did not incubate its eggs like other birds but depended upon the sun and the heat of the decaying vegetation to hatch them. The eggs are white when first laid but soon become discolored. The young grebes, when first hatched, are curious little creatures covered with down and

Photo A. A. Allen

A WATER BABY'S FIRST SWIM

Pied-billed grebe, nest and young.

striped black and white very differently from their parents. They are able to swim almost as soon as hatched and follow the old birds about the pond. When the young get tired, they climb on to the backs of their parents and in case of alarm, the old birds cover them with their wings and dive from sight, coming up among the reeds where they can easily hide. The pied-billed grebes are found in summer from British Columbia to Chile and Argentina, having one of the most extensive breeding ranges of any bird, and in winter from Maryland southward.

HERRING GULLS ON THE CITY'S WATERFRONT

The graceful gulls and terns

To those who go down to the sea, there is no bird more familiar than the sea-gull (family *Laridæ*). It matters not that there are fifty different kinds of gulls in the world with as many different names. All of the long-winged graceful white birds that follow the ships the world over or congregate in large flocks in the harbors are everywhere called sea-gulls and always will be. Absolute masters of the air they seem, for no storm is so severe that they cannot still be seen, now circling high over head, now gliding close to the waves, now sailing apparently straight into the wind without a movement of the wings. Sometimes they sail, for hours at a time, by the stern of the ship, taking advantage of the air currents and never moving their wings except occasionally to alter the angle at which they are held. Again they are seen tossing about on the waves, for they have webbed feet and can swim like ducks.

The majority of gulls are pure white except for a pearl-gray mantle and black tips to the wings, but some have the mantle darker and others have the head black during the summer, while still others have the entire plumage white with scarcely a mark. Immature gulls are darker than the adults, being dusky or grayish and changing gradually through two or three years to the plumage of the old birds.

Gulls vary in size from that of a pigeon to that of an eagle, although they are always more slender than the latter. As a group they are larger than the terns, though some of the terns are larger than the smallest gulls. The majority of terns are about the size of slender pigeons but some are not much larger than the largest swallows. Indeed, they are sometimes called "sea-swallows" because of their long pointed wings, deeply forked tails and light airy flight.

Terns do not often sail like the gulls, but few birds excel them for gracefulness. With measured beats of the wings, almost suggestive of the motion of a butterfly, and with their bills directed downward as

they watch the water, they beat back and forth along the coast hunting for small fish. Once a flock of terns locates a school of small fish, a scene of intense animation follows. The light airy flight gives way to a series of daring plunges and they dart from a considerable height into the sea, spearing the small fish with their needle-pointed bills. In this method of feeding they differ entirely from the gulls, which have hooked bills and feed upon dead fish that they find floating on the surface.

Gulls and terns are much alike in their nesting habits, for the majority of species build crude nests or lay their eggs in simple depressions in the sand or on the rocks with little or no pretense at nest building. In this respect and also in their eggs, which are olive or drab in ground color, rather heavily marked and sharply pointed, they are quite similar to the sandpipers and plovers. Indeed, they resemble the shore-birds in other respects as well and in many anatomical characters so that most ornithologists today put all of them together in one major group or order.

The commonest and best known of the 25 species of gulls that are found in North America is the herring gull. It is found throughout the northern hemisphere, nesting from northern United States and northern France northward and wintering from the southern part of the breeding range south to the Gulf of Mexico and the Mediterranean. It is common in winter in New York harbor and in other harbors, following the ferries and swooping down to pick up pieces of bread or refuse thrown into the water. It also follows the garbage scows in dense clouds and is everywhere a valuable scavenger. In the interior the herring gulls are common on all of the Great Lakes and larger bodies of water that do not freeze over, and whenever the ground is not covered with snow they make sorties on to the uplands, often long distances from water, where they find grasshoppers, beetles and grubs. Gulls always roost on the water, however, so toward night they can be seen returning to the lake just as they left it in the morning. While on the lake, in addition to picking up dead fish, they occasionally rob the loons and mergansers. Sometimes a dozen or more gulls hover over the spot where these birds are fishing, waiting for one of them to make a catch, and then they swoop down at it before it has time to swallow the fish. Usually the gulls are so persistent that the diver finally drops the fish, whereupon the gulls fall upon it and begin fighting among themselves.

Photos A A Allen

HERRING GULLS AND CROWS AT A FEEDING STATION

RING-BILLED GULL (captive)

The herring gull usually selects a rocky island for a nesting site and pulls together a small pile of drift weed for a nest. It usually lays three eggs which vary from drab to olive or bluish-white in ground color, irregularly spotted with lilac and shades of brown. The young birds are covered with down when hatched and like the adults are able to swim. They are cared for by their parents, however, until they learn to fly. Their downy coat is mottled with buff and gray so that when they crouch they are almost invisible against the lichen-covered rocks.

Ten of the fifty species of terns known to science are found in North America. They are easily distinguished from the gulls by the points already mentioned, but many of the species are distinguishable from one another only by the closest observation. The commonest color pattern is similar to that of the gulls, being largely white with pearl-gray mantles, but in the breeding season all the typical species have the whole top of the head black. Most of them, likewise, have deeply forked tails. They vary in size from the least tern, which is not much larger than a swallow, to the royal and caspian terns, which are about the size of ring-billed gulls. The caspian tern is a somewhat larger species than the royal and has a less deeply forked tail. It is likewise more northern in its distribution. The common or Wilson's tern, the Forster's tern, the arctic tern and the roseate tern are all much alike, being about 15 inches long and having the typical tern coloration. They are, however, somewhat different in habits and distribution, the common tern being the most widespread and generally seen. Close observation will distinguish the arctic tern by its grayer underparts and uniformly deep red bill, the common tern by its white throat and grayish breast and bill, red only at the base. The Forster's tern can be distinguished by its pure white underparts and dull orange bill, and the roseate tern by its delicate tint of pinkish on the underparts, but all four are about the same size and distinguishable only at close range.

Photo H K. Job

ARCTIC TERN ON ITS NEST

Photo A. A Allen

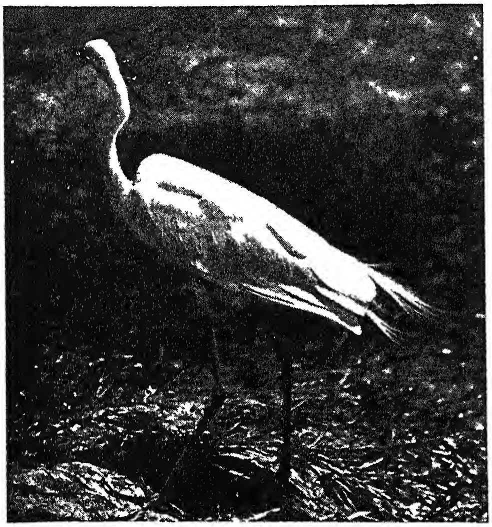
BLACK TERN AT ITS NEST

The arctic tern is the most maritime of them all and is said to have the longest migration of any bird, some individuals nesting well within the Arctic and some wintering well within the Antarctic Circle, requiring an annual pilgrimage of about 22,000 miles.

In the days when the millinery trade in feathers was at its height thousands of tern skins of all species were shipped to the New York markets and the breeding colonies all along the Atlantic Coast were almost exterminated. Indeed, even after some of the nesting islands were set aside as refuge and protected by wardens, hunters congregated on the sea near the islands and baited the birds up to them. In this way they were still able to kill hundreds of them because the terns have the unfortunate habit of hovering over a wounded companion and returning again and again, even though shot at, as though they would succor him. It was not until through the efforts of the National Association of Audubon Societies and a few far-sighted representatives and senators that laws were passed forbidding the sale of the plumage of native birds, that it was possible to save the few remaining terns. Now the birds are beginning to increase and to nest where they have not been found for years. The least tern alone seems unable to recuperate from the verge of extermination to which it was forced and it is still a rare bird all along the Atlantic Coast where once it was abundant, though recently it has shown an increase on the New England coast.

The graceful herons

When nature evolved the heron to enliven the shores, she did not take into account the avarice of man nor the vanity of woman She created a bird that



THE LITTLE EGRET

should have stood for all time as the emblem of grace. Take away the heron's life and the genius of the artist is gone — there remains an ungainly mass of spindly legs and crooked neck worthless even for

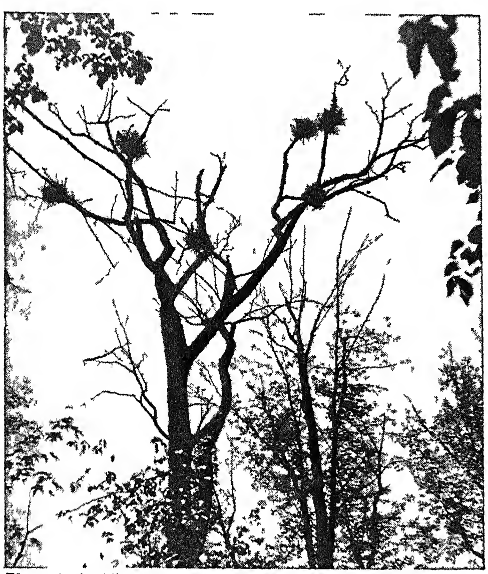


Photo A A Allen

NESTS OF THE GREAT BLUE HERON

In a dead elm in a swamp.

food. Nature might have expected, therefore, that the heron would be allowed to live and delight the eyes of mankind forever. Unfortunately, however, she decorated certain of them during the breeding season with most beautiful and delicate plumes which retained their beauty even when ripped from the backs of their owners. This signed their death warrant Shrewd milliners, playing on the vanity of women and the relentlessness of fashion, saw in these plumes a fortune. Fashion and ignorance did the rest, so that today the most beautiful species, the egrets, are nearly extinct. Indeed, they might long since have been so had it not been for the determination of a group of bird lovers who formed the National Association of Audubon Societies and for the far-sightedness of a nature-loving President of the United States, Theodore Roosevelt, who set aside certain areas of waste land as Federal Bird Reservations to give the vanishing birds a last resort of safety.

There are about 100 species of herons (family *Ardeidæ*) in the world, found mostly in tropical and subtropical regions, but at least a dozen are found in the United States and Canada. They vary in size from the least bittern, whose body is not much larger than that of a robin, to the great blue heron that stands about four feet in height. In color they vary from the streaked brown plumage of the bitterns, through various shades of blue gray and chestnut, to the snowy white of the egrets. They are variously ornamented with elongated feathers, either on the crown, foreneck or, as in the egrets, on the middle of the back. In the bittern there are some fluffy white feathers beneath the wings that are displayed during the courtship performances.

The majority of herons are gregarious birds, roosting and nesting in colonies. They scatter when fishing, however, and hunt singly, either stalking quietly through the shallow water or resting motionless along the shore waiting for some luckless fish to swim within reach of their javelin-like bills. One species, however, the reddish egret, is said to run rapidly through the shallow water in pursuit of small fish.

Most herons nest in the trees or large bushes of extensive swamps but the bitterns nest on the ground in treeless marshes. Herons' nests are always poorly made structures of sticks so thin that the pale bluish or greenish-white eggs can usually be plainly seen from below.

Young herons are covered with long shaggy down when hatched, and even before they acquire their real feathers they are able to climb from the nest and cling to the branches, using their wings and even their necks to assist them. If they drop into the water below, they are able to swim, though not very duck-like since their heavy bodies sink until only the head shows above the surface. They use their wings as well as their feet for propulsion. When alarmed in the nest or on the branches, the young herons stretch up their long slender necks and remain perfectly quiet so that they look more like sticks than like birds. They are fed in an odd manner. The old bird, having swallowed the fish or frogs which it has caught, returns to the nest with them in its crop. The young bird then seizes with a scissor-like action the base of the bill of the old bird which turns its head on one side and vigorously but deftly disgorges the food into the throat of the young.

Photo A A Allen

GREEN HERON NEAR ITS NEST

The alluring waterfowl

To one who is fond of nature in her wilder moods, there is nothing more fascinating than the flight of the waterfowl (family *Anatidæ*). Seen against a leaden sky or against the first flush of dawn, the eye follows the sweep of their rapidly moving forms until as merest specks they disappear into the haze and one is left with a feeling that nature is not yet vanquished, that there are still great spaces unexplored, that man, after all, is but one small part of the great creation. Vast stretches of brown marsh, waves lapping on the lake shore, or surf pounding on the headlands furnish the frame for a picture that clings to one's memory. There are crystals of snow in the air that cut the face as they are driven before the blast; frozen spray covers the blind and the hunters that lie in wait behind it and the floating decoys; Æolus plays a tune in the gun barrels. The uninitiated wonder how men can endure such privations and call it sport, but they have not seen the picture, nor heard the music of the wind and the waves and the whistling wings that find their response in the hearts of those who go down after ducks.

Photo A A Allen

AMERICAN BITTERN

Crouching over its young, preparing to defend them

Therefore let us wisely conserve what we have, and, as the number of hunters increases, let the open season be shortened and the bag limit lowered. Let us propagate waterfowl in captivity to restock the marshes so that our children's children may still view the picture that made its appeal to our forefathers and to us.

There are over 200 species of waterfowl in the world, of which about 50 are found in North America. They are grouped into five sub-families or groups that are rather easily distinguished: the swans, the geese, the mergansers, the dabbling ducks and the diving ducks. The swans have much longer necks than the other waterfowl, even longer than their bodies. The geese have shorter necks than the swans but longer than the ducks. The mergansers differ from all the others in their narrow, serrated bills. The dabbling and diving ducks are readily distinguished from the swans, geese and mergansers but are not so easily separated from one another unless one can observe their method of feeding or distinguish the lobe on the hind toe which characterizes the diving ducks. The dabbling ducks frequent the marshes and lake shores where they can feed in shallow water by tipping. They feed mostly at night or on dark days and spend the bright days at a safe distance from land. They usually occur in small flocks of from five to twenty, those of over a hundred being rare. They migrate earlier than the diving ducks and most of them have left the Northern States by the time the snow flies and the ponds and marshes have frozen. They winter from North Carolina to the Gulf and some species go as far as northern South America. The dabbling ducks are likewise called river ducks and summer ducks.

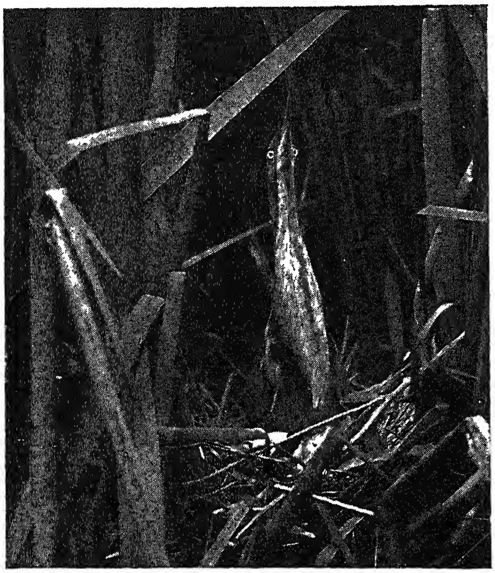


Photo A A Allen

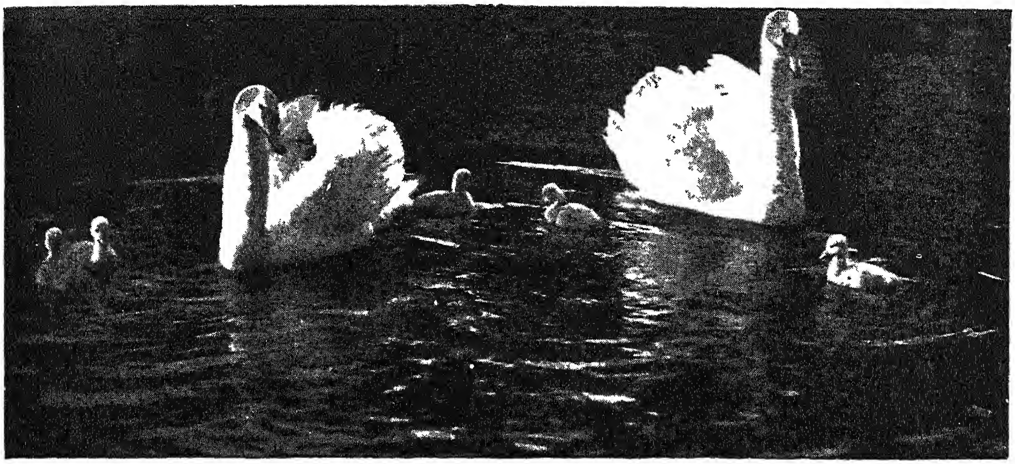
LEAST BITTERN ON ITS NEST

Assuming an attitude like a broken reed to escape detection.

The diving ducks, sea ducks or winter ducks, on the other hand, often occur in flocks of several thousand and feed in deep water, often far from land, for they dive readily and secure their food of molluscs or the roots and buds of aquatic plants in water up to 100 or 150 feet deep. They are not influenced by the freezing of the marshes and shallow water, therefore, and migrate later in the fall, and winter further north than the others. They are less exposed than the dabbling ducks to enemies while feeding and therefore feed more during the day than at night. They are better adapted for diving than the dabblers, having larger feet, stockier bodies with shorter necks and shorter wings, characteristics which enable one, when familiar with them, to distinguish the two groups of ducks on the wing at a considerable distance. On the water, the diving ducks rest lower and do not hold their tails up from the water as do the dabblers.

The swans

Of the eight species of swans, there are two found in North America. Both species are pure white except for the black bill and feet and a yellow spot between the eye and bill that distinguish these whistling swans from the trumpeter. They both resemble very closely the domesticated swan of ornamental ponds which has been derived from the European mute swan and which can always be identified by the hump or knob on its bill. The trumpeter swan is today one of the rarest of North American birds. The whistling swan still holds its own in a few places,



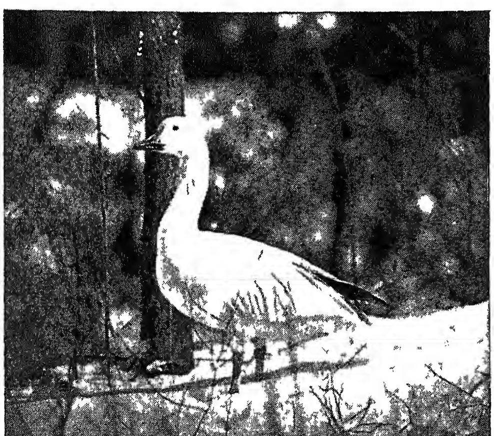
THE GRACEFUL SWANS AND THEIR CYGNETS

now that it is protected by law, and every winter large flocks congregate on Currituck Sound and a few other good feeding areas In summer the whistling swan retires to the Barren Grounds to breed, where it is said to be very conspicuous on its nest but able to defend itself against all enemies up to the size of a fox.

Swans are noisy birds and when feeding or disporting themselves their loud clarion-like notes can sometimes be heard for several miles. They can swim very rapidly and outdistance a man rowing a boat, so that they do not take wing unless hard pressed. On the wing swans are easily distinguished by their large size, long necks and pure white plumage, not even the flight feathers being dark.

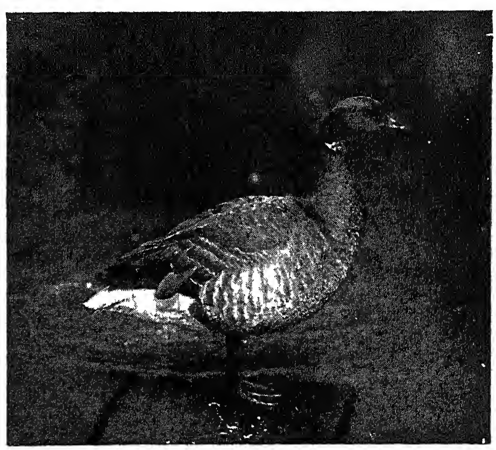
The geese

Of the twenty-five species of geese in the world eight are found in North America; of these the Canada goose is the most abundant and best known. They nest from northern United States northward to the limit of trees and winter from the Great Lakes southward to the Gulf. Their comings and goings are the most conspicuous bird migrations that we have. One hears their loud honking long before he sees them as they travel high overhead in a great wedge or Y, led probably by an old gander. They migrate both by day and by night and sometimes on foggy nights apparently get lost and are attracted by the city lights and swing low

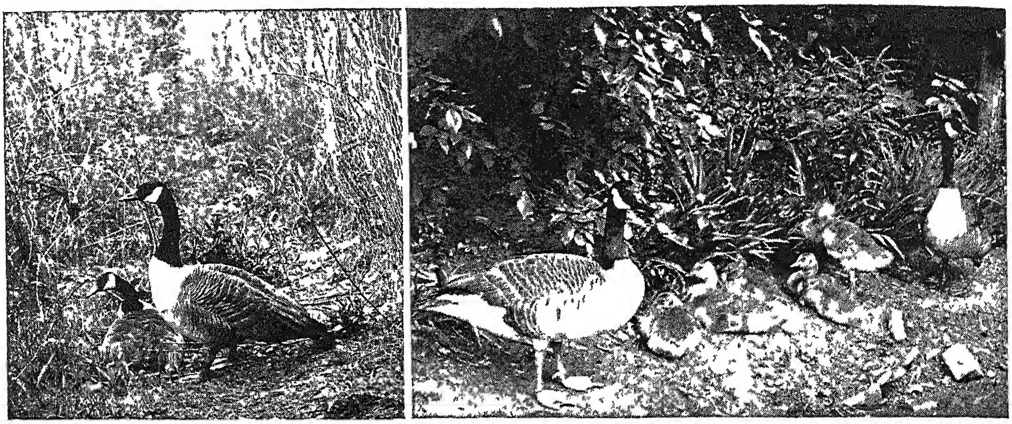


Photos A A Allen

A LESSER SNOW GOOSE
The bird (captive) is shown in winter.



BRANT GOOSE (captive)
A common goose along the Atlantic coast.



Photos A A Allen

CANADA GEESE (in captivity)

A pair at their nest, the gander standing guard — A pair with their young, the gander at the left, the goose at the right

over the housetops honking loud enough to waken even the soundest sleeper. On their migrations they are great vegetarians and are fond of grazing on the young wheat, both in the spring and in the fall. In the South on their wintering grounds, however, they seem to prefer to feed in the shallow water of the bays and lagoons, tipping for aquatic plants and organisms like the dabbling ducks.

Geese are said to mate for life and certainly in captivity it is difficult to get old birds that have lost their mates to make another choice The male goose is a dutiful husband and assists his spouse in guarding the eggs and caring for the young. He is able to deliver a severe blow with his wings, which are armed with bony knobs at the first joint, and he is, therefore, far from helpless even when he has shed all of his wing feathers and is unable to fly.

The Canada goose differs from the other species in having broad triangular patches of white on the cheeks which meet on the throat The Hutchins, white-cheeked and cackling geese are western representatives of the Canada goose The two species of brant are similar to the Canada geese in having the head and neck black and the body grayish brown, but the white is confined to a few white streaks forming a collar on the neck. They are considerably smaller and are confined mostly to the seacoast, the black brant to the Pacific Coast and the common brant to the Atlantic. The snow geese are easily recognized because they are pure white except for their black flight feathers The eastern greater snow goose is larger than the western lesser snow goose A still smaller and rarer species, the Ross snow goose, is likewise found in parts of the West In Alaska there is another species, the Emperor goose, which rarely comes south into the United States. It has a white head and tail and a bluish gray body more or less specked with white. The chin and throat are dark, a constant difference from the rare blue goose, which is a similar looking bird, of eastern North America. The breeding range of the blue goose in northern Canada is unknown but it winters in considerable numbers in Louisiana. The white-fronted goose is very similar to the European grayleg goose and therefore to our domestic geese, which have been derived from it, with the exception that the region around the base of the bill is white in the native species.

The fish-eating mergansers

The mergansers, sheldrakes, saw-bills or fish ducks, as they are variously known, form a very distinct group of waterfowl, easily distinguished by their narrow serrate bills and their crested heads. Three of the nine species are found in North America but they are not valued as food because of their fish diet. Individuals of the two smaller species, the hooded and red-breasted mergansers, however, are

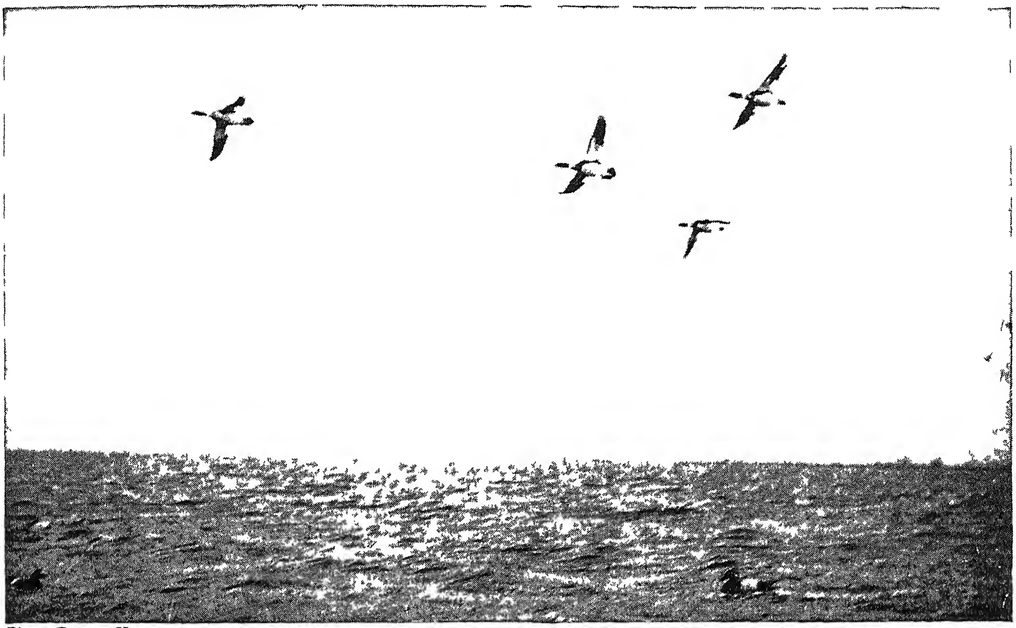


Photo Francis Harper

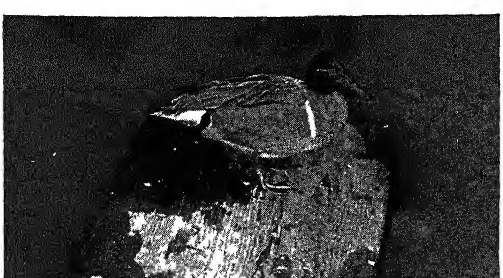
RED-BREASTED MERGANSERS PASSING OVER DECOYS

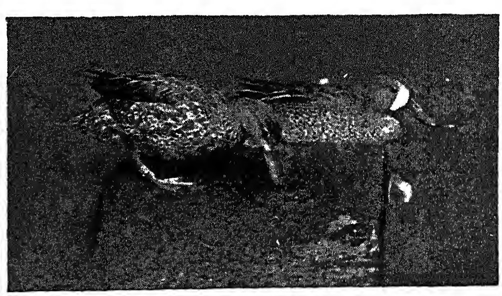
often eaten and are pronounced as good as many of the true ducks. The females of all three species are grayish birds with conspicuously crested, reddish-brown heads, the crest of the small hooded merganser being the largest. The males are conspicuously marked black and white birds, the male hooded being one of the most ornate of the waterfowl.

Mergansers secure their food by diving and pursuing it beneath the water, using only their feet for propulsion They first locate their prey by lowering their heads until their eyes are beneath the surface film and they can often be seen swimming along in this attitude. Their serrate bills with the hook-like nail at the tip seems well adapted to holding their slippery prey. Mergansers nest either in holes in trees or in crevices in the rocks and, like other ducks, lay whitish unspotted eggs.

The dabbling ducks

All the domestic ducks, and most of the ducks that are commonly known, belong to this group. Indeed, all the breeds of domestic ducks from the white Pekin to the Indian runners, with the exception of the muscovy are thought to be descended from one species, the mallard or common wild duck, which is a typical member of this group. The muscovy is a very distinct species native to the West Indies and northern South America. The wild





Photos A. A Allen

MALE GREEN-WINGED TEAL AND A PAIR OF BLUE-WINGED TEALS (captive)

The green-winged teal is the smallest of our ducks

mallard differs but little in coloration from the domestic breed, the males having bright green heads and white rings around their necks and the females being uniformly streaked yellowish or grayish brown. Under domestication mallards change considerably, becoming much heavier, and having fatter heads. In the wild state the mallard is found all over the northern hemisphere, though in North America it is more abundant in the West and in the Mississippi Valley than in the East. Here its place is filled by the black duck or black mallard, as it is sometimes called, a warier species that is better able to take care of itself in more closely settled districts. Male and female black ducks are alike except for their bills, which in

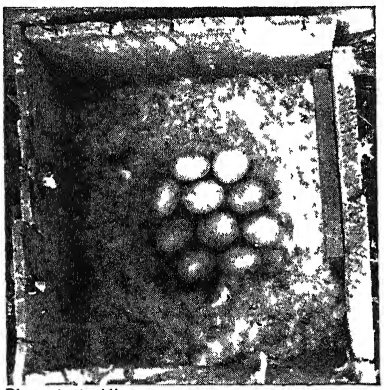


Photo A A Allen
NEST AND EGGS OF THE WOOD DUCK
(in captivity)
The down has been plucked by the female from her own breast.

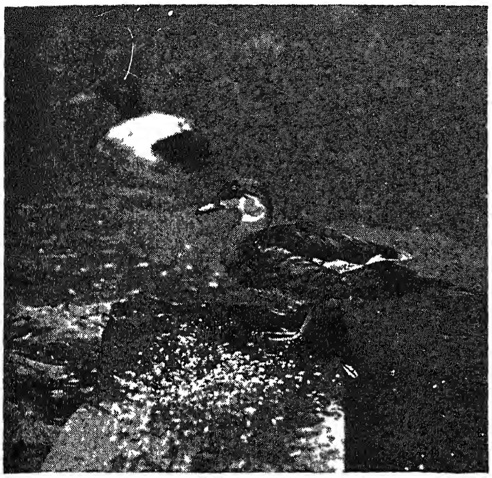
the males are yellow and in the females olive. They are uniformly brownish black except for snowy white lining of the wings which likewise contain purple patches. Both the black and mallard ducks feed to a considerable extent in the grain fields in the northern states, spending the day out at sea or on the larger bodies of water and feeding only at night. They are likewise residents of the marshes where they are most successfully hunted.

Space permits only a mention of the other dabbling ducks, of which there are ten other species found in North America. The best known of these are the pintail, the baldpate, the shoveler, the gadwall, the blue-winged and green-winged teals and the wood duck, the last being the most brilliantly colored of all. Its crested purplish green head, variously marked with white, its purplish chestnut breast and its buffy flanks all tend to make it a striking bird much desired on ornamental ponds. The males of the other species are quite beautifully marked in their breeding plumage with whites, browns, blues and metallic colors but the females are uniformly plain. The fall plumage of the male birds, which is donned in late summer and worn for but a short time while the flight feathers are being replaced, resembles that of the females which is the same throughout the year. This early fall plumage of the males, which is never worn all winter as with most birds, is called the "eclipse" plumage. It serves to make the birds less conspicuous during the period when they are replacing their flight feathers and are comparatively helpless, for unlike most birds these feathers are all shed simultaneously and the bird is without the power of flight for several weeks until the new ones are grown.

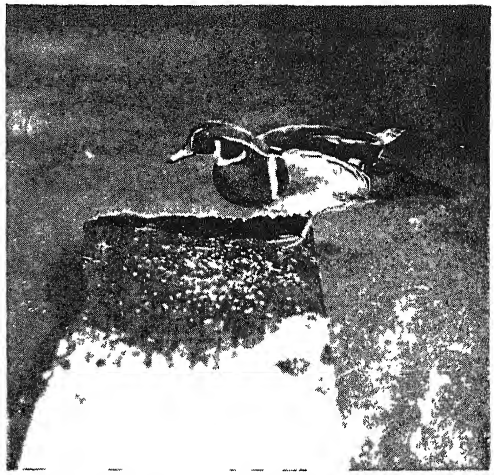
With the exception of the wood duck, all of the dabbling ducks regularly nest on the ground, usually near water, but sometimes a half a mile from it and in quite exposed situations. The nests are crude affairs of grasses and weeds, but as incubation proceeds the female plucks down from her breast with which she covers the eggs to make them inconspicuous and to keep them warm when she leaves them to feed. For the males never assist in household cares, but as soon as the eggs are laid they congregate in flocks by themselves and show no further interest. The wood duck is a notable exception for in the first place it nests in a hole in a tree and in the second place the male attends the female and assists in incubation and such care as the young receive.

The wood duck has always been much in demand because of its bright colors, and as it is not a very wary bird, it has fallen an easy prey to gunners until it has become very rare over a large part of its extensive range. Fortunately it is now quite easily reared in captivity and is therefore in no danger of absolute extinction.

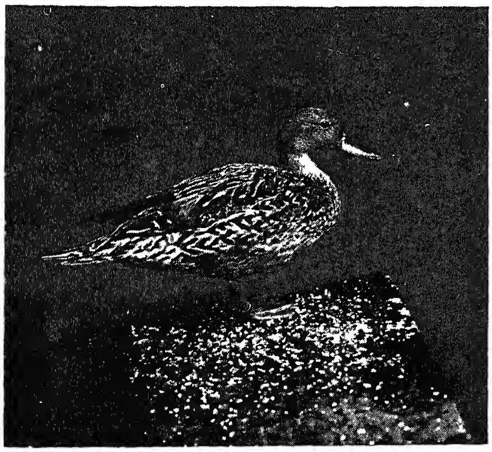
SOME DABBLING DUCKS



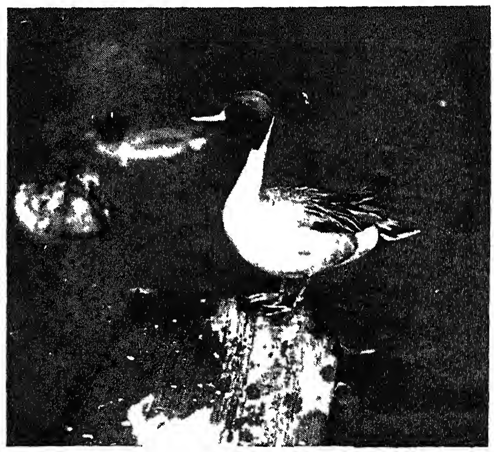
MALE WOOD DUCK IN ECLIPSE PLUMAGE
Worn during July and August.



MALE WOOD DUCK IN BREEDING PLUMAGE
The most beautifully colored of all our waterfowl.

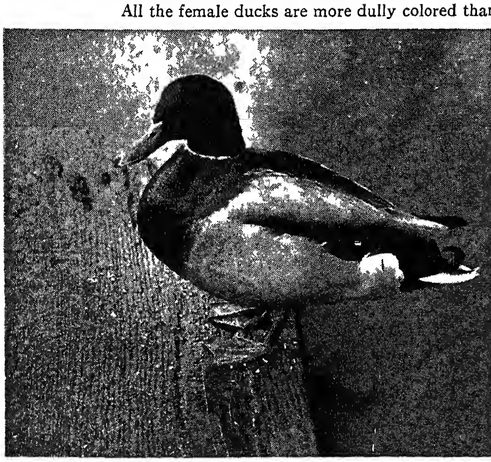


FEMALE PINTAIL DUCK

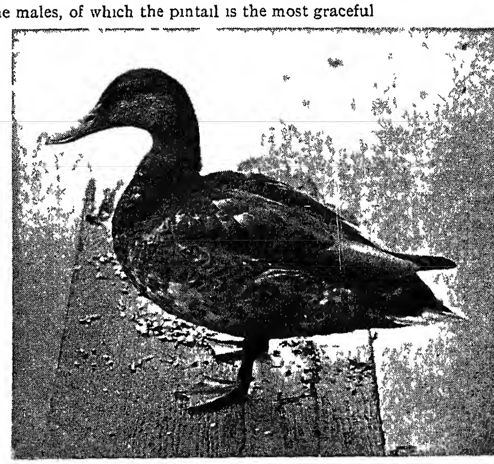


MALE PINTAIL DUCK

All the female ducks are more dully colored than the males, of which the pintail is the most graceful



MALLARD DRAKE (captive bird)
In breeding plumage.



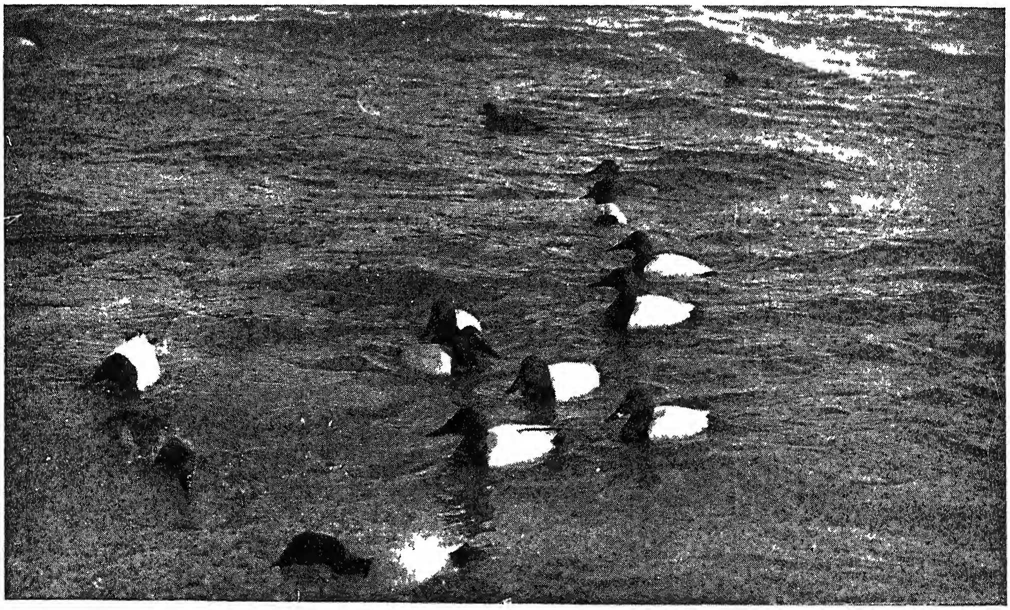
THE SAME DRAKE IN A DIFFERENT SUIT
In eclipse plumage.

The black and white illustrations on this page and the succeeding pages of this chapter are from photographs by A. A. Allen.

The diving ducks

There are seventeen species of diving ducks found in North America, some of which are very abundant, flocks of several thousand scaup ducks, for example, being a not uncommon sight on our larger bodies of water The diving ability of these ducks can scarcely be exaggerated, for some members of the sub-family, notably the old squaws, are repeatedly captured in gill nets set for fish in from 100 to 150 feet of water Indeed, almost every year in the Great Lakes, thousands of these ducks are said to become entangled in the nets and drowned The old squaws, scoters and eiders are believed to use their wings as well as their feet in diving, but the rest use only their feet which are much larger than in the dabbling ducks Their feet are likewise set farther back so that when on land they stand more erect or rest on their breasts and walk with difficulty In nesting they prefer the marshes so that they can slip from their nests into the water without having to walk on dry land With one exception they are northern breeding ducks, nesting from the northern tier of states northward

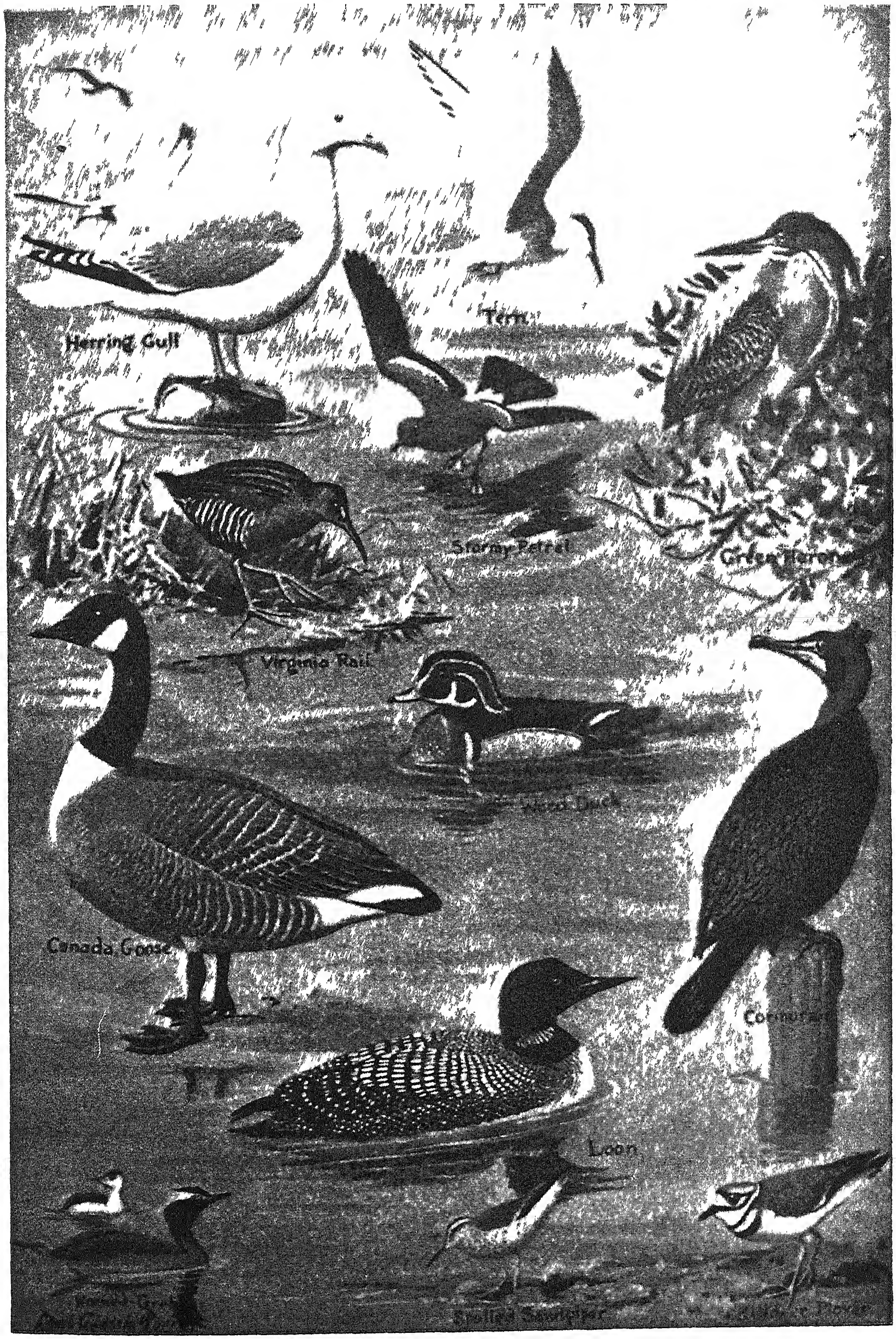
The choicest of all the diving ducks is the canvasback, so called from the white back of the male The back of the female is gray and the head and neck cinnamon brown instead of rufous as in the male A somewhat similar species is the redhead whose head is brighter red and whose back is grayer, not to mention other differences The long bill and sloping profile of the canvasback is a good distinguishing mark in any plumage The reputation of the canvasback has been gained largely through its habit of feeding upon the wild celery (*Valisneria*) which is believed to impart the pleasant flavor Other ducks feeding upon the same food are said to be quite as well flavored



CANVASBACKS ON CAYUGA LAKE IN WINTER

Other ducks of this group are the greater and lesser scaup ducks, bluebills, broadbills or blackheads as they are variously called, the ring-necked duck, the curious little ruddy duck with its upturned tail, the two species of golden-eye and the bufflehead which nest in trees, the scoters or sea coots of three species, and the four species of eider ducks from which comes the eider-down of commerce, though most of it is secured from the European birds The down is secured by robbing the nests of the down which the female bird pulls from her own breast to cover the eggs

SOME COMMON AMERICAN WATERBIRDS



In Iceland and other northern countries where the birds occur, the wild birds are induced to nest in places made for them, and they live in an almost semi-domesticated state because they are given complete protection.

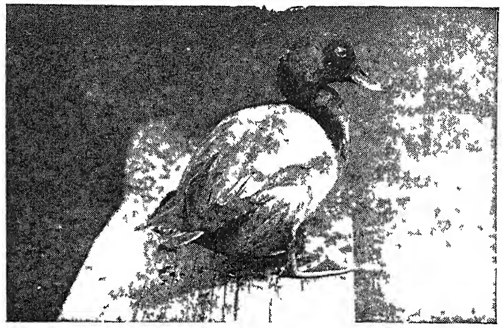
The Labrador duck, which once occurred in winter along the Atlantic Coast as far south as New Jersey in considerable numbers and which is now extinct, also belonged to this group of diving ducks. The last specimen of this duck was taken in 1871 and the cause for its extinction is not known It is suggestive, however, of what may occur to many others of our ducks if constant watchfulness is not maintained to adjust the protective laws to any decrease that may occur The wild fowl are a great asset to the country and we cannot afford to lose them. So we must keep up a constant vigilance to see that our laws give them all the protection they need and that these laws are respected and enforced.

Marsh-loving rails, gallinules and coots

"Thin as a rail" is an expression that applies as well to any of the members of this family of curious birds as it did to the parts of Abraham Lincoln's famous fence. For they are marsh dwellers, and nature has seen to it that their bodies are much compressed, shaped like that of a flea, to enable them to slip better through the dense vegetation.

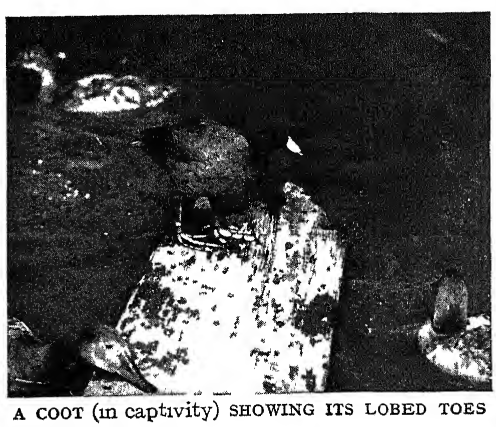
There are about 180 species in the family (*Rallidæ*) but only 15 are found in North America and of these but 4 or 5 are common even in the most suitable localities. By most people they go unseen and unknown, for unless one haunts the marshes he is apt never to see one. When a coot or a rail meets with an accident on its migration and is picked up by the corner grocer or the editor of the local newspaper, it always causes considerable excitement in the community, for it is usually diagnosed as a hybrid between a duck and a chicken or, if one of the smaller species, a cross between a snipe and a quail.

All the members of the family have rather long, stout legs like fowls, but their toes are always long and slender to distribute their weight better when running over the soft ooze or the floating vegetation. The coot has lobes on each side of its toes to assist it in swimming, for it is much more aquatic than the other species and often assembles on the open water in large flocks like ducks. All species have longer necks than ordinary birds and much shorter tails which, like domestic fowls, they hold erect when walking. Their wings are short and rounded, which adds to their chicken-like appearance, but their feathers are longer and softer than chickens', giving their plumage a somewhat hairy appearance. The gallinules and coots, the sora, yellow and black rails, have short, thick, pointed bills, but the Virginia clapper and king rails have rather long, slender and somewhat decurved bills.



A RED HEAD DUCK (captive bird)
Note the large feet, set far back

The coot and the Florida gallinule, which are perhaps the best-known members of the family, are sometimes called mud hens or "water chickens". They are similar in general appearance, being uniformly slate color and about the size of bantams.



A COOT (in captivity) SHOWING ITS LOBED TOES

FLORIDA GALLINULE ON ITS NEST

If one cannot see the lobes on the toes of the coot, another good field mark is the ivory-white bill which in the gallinule is red and green. Both species have what is called a frontal shield, a horny prolongation of the bill on the forehead, which is not found on any of the rails. In the gallinule it is bright red and quite conspicuous but in the coot it is smaller, brownish and inconspicuous. When swimming both species are quite duck-like but their heads are smaller and they are continually jerking them after the manner of pigeons. When flushed they patter along the surface for a considerable distance before they rise, but when fully on the wing they resemble small ducks. When on land or stepping along the border of a marsh, on the other hand, they do not resemble ducks in the least but appear more like busy little hens, picking at every-

SORA RAIL APPROACHING ITS NEST

thing as they step along, but lifting their feet rather high and putting them down carefully as though they were always sneaking up on some wary insect or crustacean. They are never as cautious, however, with their voices, and some of the most startling sounds that ever come from the marshes can be traced to them. Their ordinary calls are somewhat hen-like: *cut-cut*, or *cak-cak*, but occasionally they give vent to a thunderous, WUP, PUP, PUP, PUP, PUP or WUP — WUP — WUP. Like the rails they are especially noisy early in the morning and toward dusk and occasionally break out in the middle of the night.

They build their nests of dried rushes close to the water level in the marsh vegetation, the coot usually in deeper water than the gallinule and in more open situations. Often they have to add to their nests during periods of high water to keep the eggs dry. The eggs are buff in ground color, rather evenly marked, the spots on the coot's eggs being smaller and blacker than those of the gallinule.

The young birds are covered with black down when hatched, the coots being curiously ornamented with a fringe of orange whiskers. They are able to run and swim shortly after hatching and follow their parents about, hunting for food. It is an interesting sight to see a family of gallinules threading their way along the border of a marsh, the old ones continually calling and the young constantly peeping so that they will not get lost. As though to give the young something to follow, the old birds continually flash their white under tail coverts as they jerk along. At times the young get tired and crawl up on the back of the mother or again she calls them all to her and broods them for a while on little platforms of rushes or temporary nests which she constructs.

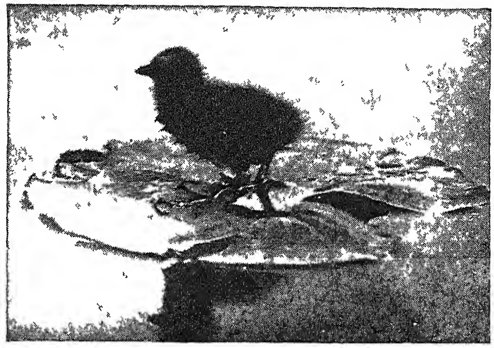
The commonest and best known of the rails is the Virginia rail, a bird about the size of a robin but of very different shape with its small head, long bill and long legs. In general color it is dark brown, somewhat streaked on the back, redder on the breast, the flanks being barred with black and white.

It is found even in the smallest marshes, from the Atlantic to the Pacific, nesting from the Middle States to Ontario and British Columbia and wintering from the southern parts of its breeding range to Central America. It is often heard but seldom seen, for it is rather difficult to flush even when one follows its notes out into the marsh. It seems to prefer to dodge through the thick vegetation like a mouse, sometimes when cornered doubling back almost between one's feet instead of flying.

Rails, gallinules and coots are all considered game birds and are shot in considerable numbers, especially in the South. The rails are very small, however, their flesh is of inferior quality, and they are such weak fliers that they furnish a very low grade of sport for hunters.

The sandpipers

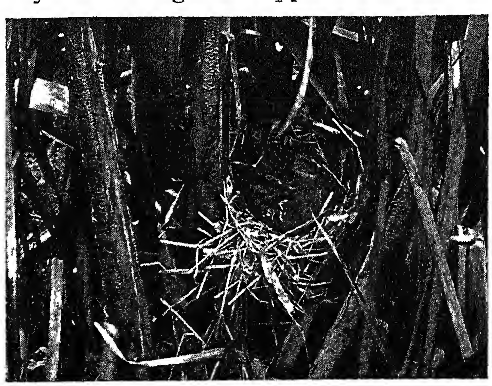
When the waters in our lakes and ponds recede during late summer and leave exposed great areas of soft mud, they would become very unattractive were it not for the flocks of graceful little birds that assemble upon them. With jerking heads or tilting tails they trot along the soft oozy shore in search of the larvæ that lie concealed in the mud. These are the sandpipers (family *Scolopacidæ*). There are tiny ones, smaller than sparrows, and there are larger ones as big as pigeons; sometimes in separate flocks; sometimes all mingled together. They are brownish or gray above and white below, with slender legs and long slender bills, and except for their size all look much alike.


YOUNG GALLINULE A FEW HOURS AFTER HATCHING

It takes a sharp eye to distinguish the different species when they have assumed their fall plumages. But it is in this plumage that we see the most of them, for on their way north in the spring the waters are high, mud flats are scarce, and they are in a hurry to get to their nesting grounds. In their breeding plumage many of the species are strikingly marked with black or chestnut and are easily distinguished from one another, but in the fall it is different. They constitute a post-graduate course in bird study that appeals to those who have passed through the warblers and the sparrows and the flycatchers and are ready for more difficult problems.

Together with the plovers, the avocets and the stilts, the turnstones and the phalaropes, the sandpipers make up the great group of shore birds. The plovers have much shorter bills than the sandpipers, the avocets and the stilts much longer legs, the turnstones squarish bills, and the phalaropes, lobed toes, but they are all very similar in general appearance.


VIRGINIA RAIL APPROACHING ITS MARSH NEST


VIRGINIA RAIL INCUBATING

SPOTTED SANDPIPER STEPPING ON TO ITS NEST

There are about 100 species of sandpipers, most of them being confined, except on their migrations, to the northern parts of the northern hemisphere, many of them nesting within the Arctic Circle. One-fourth are found in North America, some of them confined to the West, some to the East, but the majority nesting in the Far North and following in their migrations the routes of abundant food. Thus they are more common along the sea-coast.

They are great travelers, perhaps the greatest of all, some of them traversing the entire length of both continents in their migrations. The majority of species spend the summer in the Far North and, in the fall, though some of them stop on our Gulf Coast, the majority speed on their way across the Caribbean to northern South America and some continue down the coast even to Chile and Patagonia. When they leave their summer homes they have stored up great layers of fat, but when they reach their winter quarters, the majority have grown thin. Particularly is this true of those that follow the route of the golden plover on the long flight from Nova Scotia to Venezuela or from Alaska to the Hawaiian Islands without a single stop. Twenty-five hundred miles in a single flight seems almost incredible, but such is the accepted belief today with regard to the plover and other shore birds that accompany them. Indeed they have been seen passing over the Lesser Antilles as though untired and continuing on to the mainland of South America though good stopping places were plentiful. When instinct compels birds to make such a trip, it is little wonder that it carries some of them on southward far beyond the bounds of reason and good sense, even to Cape Horn, perhaps 9000 miles from their nesting grounds.

In former years all of these shore birds were considered game birds and were shot in such numbers that some of the species were nearly exterminated. This was possible because they ordinarily fly in close flocks so that many can be killed at a single discharge of the gun. Now, through the Migratory Bird Treaty with Great Britain, they have passed under federal jurisdiction and all save a few species are given protection. Of all the shore birds, only the yellowlegs, Wilson's snipe, woodcock and the black-bellied and golden plover remain on the game list for which there is an open season.

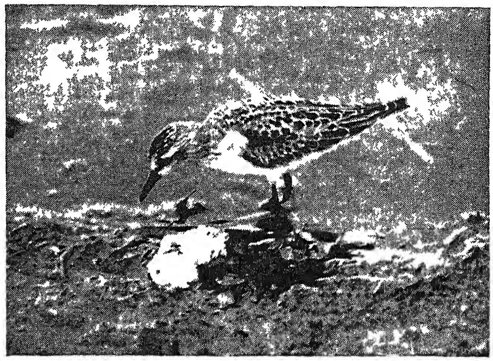
The commonest species of sandpiper is the spotted sandpiper, "tip-up" or "teeter-tail", as it is variously called. In summer it is found along almost every stream and lake from northwestern Alaska to Louisiana, and in winter, from Louisiana to southern Brazil. It can be distinguished from the other sandpipers of its size, about that of a sparrow, by the conspicuous spots on its underparts. In the fall, however, these are lost, when it would be hard to identify were it not for its constant teetering. Several other species, and especially the solitary sandpiper, jerk their heads when they walk but the spotted teeters its tail or its whole body as though it has difficulty in balancing on its slender legs. It flies with a peculiar hovering movement of its wings which show a narrow gray line down the middle. The Wilson's snipe is quite different from other sandpipers and prefers the grassy marshes and seldom ventures out on the bare flats except early in the morning and at dusk. The Wilson's snipe is a better game bird than the other small sandpipers because of its habits. It sometimes travels in flocks but they scatter when feeding and do not get up together nor afford a "pot" shot. They ordinarily escape detection until they jump with a somewhat startling "kick" or "bleat" and quickly get off on a zigzag course that puzzles the hunter.

Even more aberrant among the sandpipers and the best game bird of them all, is the woodcock. It never ventures out into the open except after dark, but spends the day usually in alder thickets, though sometimes at a considerable distance from water. Because of the nature of its haunts, it makes a difficult target for the hunter. It has, however, the unfortunate habit of never flying very far and allowing itself to be flushed and shot at time and again. Once in its winter quarters in the South, it remains in the same thickets until time to move northward again, so that hunters with dogs have nearly exterminated all the birds wintering in some localities.

The woodcock is one of the most protectively colored birds that we have and, on the nest, it frequently relies entirely upon its coloration and will allow itself to be touched while incubating.

With the exception of one species, all of our sandpipers nest on the ground. The exception is the solitary sandpiper which, so far as is known, utilizes the old nests of other birds like the robin and grackle, sometimes at a considerable distance above ground and away from the water. All sandpipers lay three or four very large eggs for the size of the bird, which are sharply tapered so that they will fit together like the pieces of a pie. Otherwise the old bird would be unable to cover them. They are usually buff or tan in ground color, with some species greenish, heavily spotted with black or brown.

Young sandpipers are covered with down when hatched, many of a striped pattern, and are able to run about and follow their parents or even swim across streams. The first plumage is similar to that of the adults in the fall, and in the spring all molt into the breeding plumage. If there is a bright plumage, females don it as well as the males. Indeed, among the phalaropes, which are closely allied to the sandpipers, the females are brighter than the males. It is interesting to note that with them the males are left to incubate the eggs and care for the young, while the females assume no responsibilities except laying the eggs.



SEMI-PALMATED SANDPIPER FEEDING

The food of the sandpipers includes many mosquito and fly larvæ, and among some species grasshoppers and other destructive insects. On the whole, however, the sandpipers commend themselves to us more because of their graceful appearance and charming ways. Our shores and mud flats would be desolate indeed with no birds to enliven them, and most people are glad to see all the smaller species removed from the game list.

The plovers

If travel is an education, the plovers must be an educated family (*Charadriidæ*). With their near relatives the sandpipers, they hold, with one exception, all records for long-distance flights. The one exception is the arctic tern, which nests within the arctic circle and winters within the antarctic, traveling some ten thousand miles over the sea twice a year. When it comes to actually seeing the world, however, there is no bird to compare with the

THE SANDERLING ON THE BEACH

golden plover. This bird nests on the arctic shores of North America and then flies southeast to Labrador, New Brunswick and Nova Scotia. The 2500 miles of sea between Nova Scotia and South America hold no fears for it, and a direct flight is made over the Bermudas and Antilles, often without a stop. The journey is then continued through Venezuela and Brazil to the pampas of Argentina. But not content with seeing this much of the world, this inveterate tourist seeks a different route for the return journey. Starting northwest from Argentina, it crosses Central America and enters the United States by way of the Gulf, traveling up the Mississippi Valley to Manitoba and Saskatchewan and thence to its breeding ground along the arctic shores. The two routes are fully 1500 miles apart.

KILLDEER PLOVER STANDING OVER ITS EGGS

The western golden plovers often start from Alaska for a direct flight to the Hawaiian Islands and thence to the islands of the South Sea. The golden plovers that nest along the arctic shores of Europe and Asia and winter from India to South Africa, are only slightly different from the American birds, and should we include them we may certainly claim the whole world in the range of this remarkable bird. It is somewhat smaller than a pigeon, with long pointed wings. Its upper parts are spotted with golden yellow and black, and its underparts are uniformly black in summer and grayish white in winter. A white stripe from the forehead down the side of the neck and breast is conspicuous in the summer plumage when set off against the black underparts.

Very similar to the golden plover is the black-bellied plover, which has a similar change of plumage with the seasons but always lacks the golden yellow spots of the upper parts. It is equally cosmopolitan, and in eastern North America, at least, is a more common species. Some of them pass the winter as far north as North Carolina, but others continue their flights to Brazil and Peru. Both species are similar in habits, frequenting shores and mud flats or even plowed fields or pastures. They fly in close flocks and appear like small ducks at a distance. Upon alighting they scatter to feed, running along the beach in search of stranded aquatic insects and crustaceans, which they pick up with a vigorous tilt of the body as though they were about to dive.

Both the golden and black-bellied plovers are still numbered among the game birds and are hunted either by means of decoys or by stalking them along the shore. They have rich mellow whistles which are quite easily imitated and they may often be drawn down to the decoys from a great height by the hunters.

There are about 75 species of plovers in the world, of which only 8, including the two mentioned, are found in North America. Of these, the most common is the killdeer, so called from its notes: "kill-dee, kill-dee, kill-dee", which constantly fill the air wherever these birds occur. They seem to have petulant dispositions, and find expression for their feelings through constant noise, so that the slightest disturbance or alarm starts them off. The majority of shore birds are confiding creatures, and unless constantly shot at will allow even the hunters to approach quite closely. Not so with the killdeer; it seems to have a special abhorrence of man and always espies one approaching at a great distance and starts "kill-deeing" so as to alarm the whole flock, and long before the other shore birds take wing it pitches off on a swift, erratic flight to some distant part of the shore. Its wings are long and pointed, and the speed which it develops when once under way is as remarkable as the irregular course which it often pursues.

INSTINCT AND EMOTION

The Deep-Seated and Universal Influence of Instinct, and Its Inseparability from Emotion

THE MODERN STUDY OF PSYCHOLOGY

WE are now about to plunge into what St. Augustine called "the abyss of the human mind". We have studied the senses, the memory, the mechanism of speech, and we have to look now at what Wordsworth called "the very pulse of the machine". It feels, is impressed, combines and retains impressions, but, furthermore, it does things. Why and how? All that we have yet dealt with is only preliminary, after all, though there are many textbooks which deal with nothing else, as if the intelligence were the whole of man. The intelligence is only a method, a mechanism, a mode of direction—for the purposes of that whose purposes they are, and whose intelligence it is. We must get down to the springs of action, to the very pulse of the machine.

In the study of reflex action, we saw how living creatures, including ourselves, may and do respond to stimuli. Light is felt, and the pupil of the eye contracts; a fist approaches, and the upper eyelid falls; we sit on a pin and rise rapidly, perhaps with a reflex expletive in addition. These are more or less simple reflexes, or reflex actions, and the study of them does not take us far enough when we want to understand the behavior of man. Nevertheless, we note that these responses, though in a sense automatic and mechanical, are yet not without meaning. They are for life. They express the intention and purpose and construction of the living thing *to live*. They are the mechanical expression of purpose, just like a machine, a gun, a locomotive or an electric piano, made by man and caused to "go" by means of the appropriate "liberating stimulus".

When we look at certain other kinds of behavior, evidently more complicated, such as throwing oneself into a fighting attitude or into another person's arms, or when we see a puppy or a child devoting itself to the examination of some novelty, we recognize a sort of resemblance to mere reflex action. These higher types of action we call "instinctive"; and we know that a vast variety of human behavior, in small things and in great, belongs to this class. It is instinctive, natural, follows impulses which arise within us, of which we are conscious, but which, in a sense, we cannot be said to have invented. We "find ourselves irresistibly drawn" to do this or that, as the moth flies to the light, or the infant's hand feels for its mother's bosom. If we believe in the doctrine of organic evolution, as we all do, we must try to trace and define a connection between those lowest forms of conduct by which, say, the amœba, "sensing" something edible, approaches it, and those by which a hungry man follows a sniff of an adjacent restaurant, or works night and day for money wherewith his children may be fed when he is dead.

The first, and in many ways the greatest, student of this subject was Herbert Spencer, whose "Principles of Psychology", has now passed its sixtieth birthday. Having recognized the theory of evolution to be a universal truth, Herbert Spencer sought to apply it to the evolution of mind. Thus he reached the conclusion that "instinct may be described as compound reflex action". In the simplest reflex a single impression educes a single response; in the working of instinct many

impressions combine to produce a manifold response; "and the higher the instinct, the more complex are both the directive and the executive coördinations".

Probably Herbert Spencer cannot guide us much further in this direction. We are grateful for his help thus far. No doubt his definition is true and useful as far as it goes. But, after all, it is only a physiological definition; it is only in terms of machinery, and it does not even allude to the psychical side of what is going on. Now, there *is* a psychical side. We may observe the amœba or the puppy, and define its actions as reflex, simple or compound. But when we proceed to observe ourselves doing just similar things, in the presence of similar stimuli — food, novelty, danger, attraction — we cannot fail to notice that there is something more than machinery to reckon with.

The combination of how we effect with how we are affected

While we do what we do we also *feel*. We enjoy, or fear, or hate, or are curious, or what not. If, perchance, we also happen to think, we shall doubtless credit the puppy, at least, with feelings not incomparable with our own; and thus we have established the fact that there is a psychical side to instinctive action. We not only effect, but are affected. Psychologists thus often and conveniently speak of the "affective" aspect of instinct.

But we heard nothing about this from Herbert Spencer, and yet it has only to be experienced at first-hand in and by ourselves for us to admit that it is at least as real and as important as anything in the world. To hate, to fear, to welcome, to love, to be interested in — these are part of the very deepest and most *e*ffective, because the most deeply *a*ffective, substance of our being. We must make a fresh study of instinct, plainly, for, in terms alike of action, of behavior and of feeling, this is at the very heart of things.

And psychologists have been studying instinct ever since Herbert Spencer laid the foundations of the new psychology, which is based upon life, and is in living contact with physiology from first to last.

Getting free from chaotic uses of the word 'instinct'

Two notable students on the subject in especial must be consulted, the late Professor William James and Dr. William McDougall, who has, by general consent, carried our knowledge of this subject further than ever before. But first, lest we lose ourselves hopelessly, we must properly define our terms. "Instinct" and "instinctive" are used so loosely in ordinary speech that they have almost ceased to have any meaning. As Dr. McDougall says: "On the one hand, the adjective 'instinctive' is commonly applied to every human action that is performed without deliberate reflection. On the other hand, the actions of animals are popularly attributed to instinct; and in this connection instinct is vaguely conceived as a mysterious faculty, utterly different in nature from any human faculty, which Providence has given to the brutes because the higher faculty of reason has been denied them."

Thus we are told that people have an "instinct of subordination", that ancestor-worship is a "mere tradition and instinct", that if a drunkard is fed on fruit he will "become instinctively a teetotaller", that "the Russian people is rapidly acquiring a political instinct", that "the instinct of contradiction, like the instinct of acquiescence, is inborn". Such absurd instances show that the words in question are commonly used as cloaks for ignorance, and are substituted for any attempt to understand individual or collective actions which we are too lazy to analyze. Perhaps everyone uses the words in such ways in ordinary speech, but they must not so occur here.

Instincts — innate elements not acquired during the individual lifetime

In our discussion of "instincts" here we shall mean what the serious students of the mind always now mean by that term — "innate specific tendencies of the mind that are common to all members of any one species, racial characters that have been slowly evolved in the process of adaptation of species to their environment, and that

can be neither eradicated from the mental constitution of which they are innate elements nor acquired by individuals in the course of their lifetime". An instinct is thus something natural, genetic and is the very opposite of a habit. Acquired habits of action, such as play a great part in our lives, may be called "secondary automatisms", and require careful study. The possibility of acquiring them may have an instinctive basis, but they are not instincts; and no writer of today who is really trying to find the facts of human nature ever says instinct when he means habit, or habit when he means instinct. Those who cannot perceive and steadily maintain in their minds the difference between what one does because one is so made, without any previous experience or understanding, or imitation or education or suggestion, and what one does because one has learned, say, to write, and with one hand rather than the other—those unfortunate people should not attempt to proceed further with psychology, where their predecessors have already caused muddle enough.

The simplest life endowed with a power of adaptation

Let us go to a great student of the behavior of insects for further illustration of this all-important distinction. In the preface to Professor Auguste Forel's book on "The Senses of Insects", we find excellent definitions of true instinct, and of its ally and opposite, which is not instinct. Instinct in insects, as elsewhere, is inherited, like limbs or heart or muscles; "it is constant in effect, adapted to the circumstances of the special life of the species . . . this curious instinctive adaptation which seems so intelligent when it carries out its proper task, so stupid and incapable when diverted to some other purpose."

But, as Professor Forel insists, and his study of insects applies no less to ourselves, the living creature has also a power of personal adaptation, a "plastic or adaptive activity", which is other than instinct, but is its equal in importance. As he says, this personal power of dealing with circumstances is primitive. "It is even the fundamental condition of the evolution of life. The living being is distinguished by its power of adaptation. The amœba is plastic." By means of this power the living creature opens up new paths for adaptation to the unexpected, preparing by repetition secondary automatic activities which we call habits Hence he reaches the following conclusion, which must be exactly quoted, for it dates as far back as 1900, and is notably similar to the teaching of Bergson in his "Creative Evolution":

A special automatic activity that reaches its summit in insects

"To sum up, every animal possesses two kinds of activity in varying degree, sometimes one, sometimes the other predominating. In the lowest beings they are both rudimentary. In insects, special automatic activity reaches the summit of development and predominance; in man, on the contrary, with his great brain development, plastic activity is elevated to an extraordinary height, above all by language, and before all by written language, which substitutes graphic fixation for secondary automatism, and allows the accumulation outside the brain of the knowledge of past generations, thus leaving to the last the forces necessary to his plastic activity, at once the adapter and combiner."

This might be a passage from Bergson, except that the French philosopher would scarcely allow even so much of instinct in the make-up of man. As the reader will remember, Bergson sees in the insect the instinctive and in man the intelligent creature, and he has very little to say of instinct in ourselves. Here he follows the older view of the psychologists of the nineteenth century, who were inclined to suppose that instinct had all but lapsed in man, and that intelligence had taken its place. They did not see that intelligence *does* nothing; it points, but it does not push. They regarded man as a creature with only very few instincts, and those weak and rather objectionable or derogatory to his dignity, for he is the reasonable creature, while the lower animals, they said, are not reasonable or intelligent, but behave in accordance with a great number of instincts with which they are endowed.

The contention that man has as many instincts as the lower animals

But, back in 1890, in his "Principles of Psychology", Professor William James set himself against the then generally accepted notions. All agree that man has had ancestors whose actions were mainly instinctive, but we can no longer assent to the view that, as man's intelligence and reasoning powers developed, his instincts atrophied, until now in civilized man instincts persist only as troublesome vestiges of his earlier state, vestiges that are comparable to the vermiform appendix, and which, like the latter, might with advantage be removed by the surgeon's knife, if that were at all possible James declared, on the contrary, and indeed proved, that man has at least as many instincts as any of the animals, and that they play a leading part in the determination of human conduct. And now Dr. McDougall writes that "this recognition will, I feel sure, appear to those who come after us as the most important advance made by psychology in our time".

No doubt the notable feature of instinct in mankind is its great modification by the intelligence, and by habits acquired under the guidance of intelligence or by imitation. Further, in man this modification is made possible by the very development of his instinctive powers — a slow development which has long caused us to misunderstand their true character, and to put down as habit what was not "second nature", but *first*. In mankind the instincts, though innate, are, with few exceptions, undeveloped in the first months of life, and only ripen or become capable of functioning at various periods throughout the years from infancy to puberty, or even later still.

A single instance will suffice to show, once and for all, what we mean by a true instinct, in a highly developed form. "The mason-wasp lays its eggs in a mud nest, fills up the space with caterpillars, which it paralyzes by means of well-directed stings, and seals it up; so that the caterpillars remain as a supply of fresh animal food for the young which the parent will never see, and of whose needs it can have no knowledge or idea."

The instinct that is in ignorance of the purpose for which it exists

Here we see, in sharp outline, that notable fact of instinctive behavior upon which William James insisted — its ignorance of the purpose for which it exists. There may be exceptions to this rule in the case of the lower animals, as there certainly are in man; but in them and in man it is true that, even though the purpose be perceived, it is not the perception of the purpose that impels to action. This is something deeper than foreknowledge, anticipation, conscious volition. How the mason-wasp, for example, can do what she does, having never done it before, having never seen it done nor having any slightest inkling of its clear, precise, exquisitely achieved purpose — that is a question which we cannot attempt to deal with now. The point is that this independence of intelligence, of memory of the past or prevision of the future, is a characteristic mark of instinct; and our appreciation of it will aid us to realize the true nature of instinct.

An instinctive basis for all behavior without exception

If the case of the mason-wasp engaged in life's eternal business of maintaining itself against death seems too remote for our own case, let us take that of the youth who falls in love. Among the higher types of men love means much more than mere "reproductive instinct", and may cease to have any effective or necessary purpose of that kind. But that is its root. Herbert Spencer long ago pointed to this case to show instinct's independence of experience. The boy has never been in love before. He may have been brought up in such circumstances that he has never seen its manifestations, or, if he has, he has laughed at them, without the slightest understanding. But now life calls to him, and it is his turn. Habit, experience, initiation, understanding, appreciation of the vital purpose of all — these are utterly absent, but the boy falls in love, nevertheless, as he was made to do Here is the case of an underlying instinct about which there could be no doubt, and of

which no one could pretend either that it was an acquired habit or that it was practically the same as one. The argument now is that, if we look more closely, we shall see the instinctive basis for other forms of behavior — for many, for *all without exception.*

We said that Herbert Spencer's definition of instinct was inadequate because it only described machinery. But instinct is palpably more than mechanical, even when we look at it from the outside. A mechanical process is arrested by any sufficient mechanical obstacle, but we all know that "Love laughs at locksmiths".

In more academic language — though no more accurately than our illustration — "the process, unlike any merely mechanical process, is not to be arrested by any sufficient mechanical obstacle, but is rather intensified by any such obstacle, and only comes to an end either when its appropriate end is achieved, or when some stronger, incompatible tendency is excited, or when the creature is exhausted by its persistent efforts".

And when we look again at an instinctive action from the inside, as we observe it in ourselves, we can recognize not only that it has its psychical side, but that this psychical side is threefold. We must understand it clearly if we are to be prepared for the great advance in psychology which we owe to Dr. McDougall, and to which we are coming. Every instinctive act involves: (1) a knowing; (2) a feeling; and (3) a trying. We see or perceive some object, we have certain feelings about it and we strive in relation to it, towards it or away from it, or for it or against it. These feelings and strivings, however we shall afterwards define them, lie very deep in our nature, and affect our estimate and valuation of life beyond all else. It is in terms of them that we find life worth living or worthless, that we are happy or miserable. In more technical language, "the continued obstruction of instinctive striving is always accompanied by painful feeling, its successful progress towards its end by pleasurable feeling, and the achievement of its end by a pleasurable sense of satisfaction".

Never again, as in Herbert Spencer's definition, must we neglect the psychical side of instinctive processes, for it is all-important. Here is the conclusion of Dr. McDougall's fine chapter, which since its publication has been read with gratitude and appreciation by psychologists throughout the world and to which every writer on these subjects must hereafter be permanently indebted.

The instincts the prime movers of all human activity

"We may say, then, that directly or indirectly the instincts are the prime movers of all human activity; by the conative [will-ful] or impulsive force of some instinct (or of some habit derived from an instinct), every train of thought, however cold and passionless it may seem, is borne along towards its end, and every bodily activity is initiated and sustained. The instinctive impulses determine the ends of all activities, and supply the driving power by which all mental activities are sustained; and all the complex intellectual apparatus of the most highly developed mind is but a means towards these ends, is but the instrument by which these impulses seek their satisfactions, while pleasure and pain do but serve to guide them in their choice of the means.

"Take away these instinctive dispositions with their powerful impulses, and the organism would become incapable of activity of any kind; it would lie inert and motionless like a wonderful clockwork whose mainspring had been removed, or a steam-engine whose fires had been drawn. These impulses are the mental forces that maintain and shape all the life of individuals and societies, and in them we are confronted with the central mystery of life and mind and will."

The myth that philosophers see things by the white light of pure reason

Observe, now, before we broach what seems to be another subject, how these conclusions bear upon the popular notion of the mind as a structure with watertight compartments. We talk and think as if the mind were really made of separate

things, such as, for instance, the intellect and the will, the realm of reason and the realm of desire. Desire is thought to be a lower type of mental component, so that the ancient stoics taught that the wise and good man must extirpate all emotion from his bosom, while even Kant taught that "he should be free from desire".

It was further supposed that not until the wise and good man had accomplished this feat could he justly and securely reason. Other people saw things through a mist of feeling and prejudice, which gave everything the *couleur de rose*, or tinged it with jaundice. But the real philosopher must see things "as they are", by the white light of pure reason, the *lumen siccum*, or dry light which faithfully recorded facts, without caring one way or the other.

If we go back to the great writers, for great they undoubtedly were, of the nineteenth century, to Mill and Spencer and Tyndall and Huxley, we find ourselves being constantly exhorted to divest ourselves of any desire to find any particular truth, but to follow the pure light of reason, wherever it lead.

The universality of desire with strong personal instinctive motive

Meanwhile their critics could not go wrong, for they had no desires or prejudices or preferences (or motives, that would mean!), but used the *lumen siccum* alone. They did not realize that without desire no one acts, and that their own faithful research and passionate exposition was the best evidence in the world that they, too, like all the rest of us, were affected by the universal tendency to know what one wants in the way of beliefs and to see that one gets it.

Professor Tyndall's famous Belfast address illustrates our point. In it there occurs the fine passage: "But there is in the true man of science a wish stronger than the wish to have his beliefs upheld — namely, the wish to have them true." A noble sentiment, which we may all take to heart; but the speaker did not realize that the scientific passion for truth has itself an instinctive basis, and that we each of us have an instinctive structure which not only determines our search for truth, but our appraisement of it and our identification of it as true. Tyndall himself says further on that "without moral force to whip it into action the achievements of the intellect would be poor indeed". Nay, more; we now see that without some kind of instinctive impulse within us, whether moral or immoral, the achievements of the intellect would be nothing at all. The "pure intellect", the *lumen siccum*, the "philosophic detachment from desire" — all these are myths, which never were nor will be. Let us aim at Tyndall's ideal, let us remember his warning, but let us fully realize, all the time, that desire, personal and particular in each of us, is the motive of all our doings, including the embrace of one we love, or the faithful calculation of angles in a trigonometrical problem. If we conquer desire and prejudice in the lower sense, that is only because we come under the sway of higher forms of desire and nobler prejudices.

The combative instinct of eminent exponents of philosophic calm

It would perhaps be worth while, and it would be only too easy, to trace the influence of desire and of prejudice in many and many an observation of the thinkers whom we have quoted. Anyone reading them now, without reference to the circumstances of the time, will marvel how Huxley could have said this, and Spencer that, and may incline to suppose that these men were sometimes very poor thinkers, after all. But reconstruct their emotional *milieu*, so that we see the entrenched forces, the bitterness, the narrowness, the insolence against which they had to fight, and we see at once that these men were themselves animated by inevitable prejudices and desires, no less certainly than the opponents whom they decried on that very same account. When a bishop could ask Huxley whether it was through his grandfather or grandmother that he claimed descent from a monkey, can anyone suppose that the *lumen siccum*, or the disengaged, volitionless, careless intellect was much more in evidence in those days than in any other?

The comparison between the emotions of man and the instincts of lower animals

In fact, everyone who has ever written a sentence of argument, or who has ever sought for facts in his life, knows all the time that he is moved by desire of some kind — moved, guided, prompted, checked; that it verily "forces" the facts upon him, from nature's pack, as a conjurer "forces" a card upon his patron. The desire may be for money, to prove oneself right, to prove one's friend right, to prove someone else wrong, to prove the rightness of the rest of one's beliefs (a dominant motive in the highest minded), to be useful, to be cheering. But there always is desire behind us all, and without it we should never stir a step, mind or body.

Let us turn now to another question. Feeling, desire, emotion — all these are words which insisted on turning up in the foregoing discussion. What, in fact, is the relation between emotions and instinct? Some relation there certainly must be. In still recent years, and even now in the estimation of those who have not followed the advance of psychology, the emotions of man corresponded to the instincts of the lower animals. The view was, of course, that man had very few instincts; little, indeed, besides the reproductive instinct — whence, by a train of morbid and childish association, the idea that instinct in general is something "low" and unworthy of man — and hence, when the evident resemblance between an angry man and an angry dog was observed, it was necessary to assume that the dog was acting — low hound — under the influence of instinct, while the man was moved by emotion.

A little honest thinking will suffice to show that there is something wrong here; and perhaps we should be nearer the truth if we dropped the assumption that the man and the dog are so utterly different, the man a "reasoning being" and the dog a mere dog, the one being guided by his Godlike intelligence and the other by its animal instincts. Indeed, we shall see in a moment how certain and evident is the truth when we do.

What the most delightful of all writers on psychology taught

But first, for the sake of the historical interest and also on account of its general acceptance by the mass of amateur psychologists today, let us look at the theory of the emotions which was independently advanced by William James and by the German writer Friedrich Albert Lange, many years ago, and which is therefore technically known as the James-Lange theory of the emotions. Beyond dispute, Professor James was the most brilliant, easy, irresistible and delightful to read of all writers on psychology. He had "a way with him" which no one could resist. Every psychologist is immensely indebted to him for his ideas, his *élan*, his fertility of illustration, and the enhanced interest which one felt in every subject which he handled. Never was man better suited for the advocacy of a brilliant paradox; and there can be few readers of psychology who have not been to some extent under his spell, above all in the case of his theory of the true nature of emotional actions and the true order of events therein.

According to this theory, which, at the time of its advancement, made a great sensation in psychological camps, we are all quite wrong when we think that we cry because we are sorry, or tremble and run away because we are afraid. That, according to James, reverses the true order of events. In point of fact, we cry or tremble instinctively, by "compound reflex action", and *then* we become conscious of the trembling, or the wet tears, or the palpitating heart, or the fleeing limbs, and this consciousness of the organic changes in our bodies is the emotion. We do not cry because we are sorry, or run away because we are afraid, but we are sorry because we cry, and afraid because we run away — or, even if we do not run away, because we feel the beating heart, the over-acting muscles of respiration, the dryness in the throat.

Thus, in Professor James Ward's words, "Professor James's main position is that an emotion is but a sum of organic sensations".

Objections to the James-Lange theory of emotional action

This is, to some extent, a theory which is capable of being put to the proof, and the evidence is against it. Professor Sherrington, of Oxford, a leading student of response, found that, after the performance of an operation which prevented impulses of internal origin from reaching the brain, dogs still exhibited the symptoms of emotion when their instincts were excited.

The facts are against the James-Lange theory, but we can all of us see that there is something in what the theory asserts. It is true that one's feeling of wet tears, a grimacing face, one's hearing of one's own sobs, contributes to the feeling of being very sorry for oneself. It is true that discomfort is increased by palpitation, and that when you run away from a noise in the dark you are more frightened than ever. It is profoundly true that, if we apply the James-Lange theory to our own conduct, we profit thereby. Put on a smiling for a depressed and drooping face, speak in a cheerful instead of a miserable voice, and you feel better. The hysterical woman, on the contrary, who was doing very well until her doctor or her husband entered the room, now speaks as if she were nearly dead, and looks as ill as possible, in order to excite the sympathy upon which she lives, and the immediate result is that she feels ill, and, in fact, is ill in some degree. These, and a hundred other instances, show that sensations from the body do contribute notably and importantly to our emotional state; and for the clear perception of this we are all indebted to the authors of this celebrated theory, but no more can now be said of it.

The probable play of emotions through an emotional center in the brain

The fact, no doubt, is that our emotions have a central seat, with contributions from the various parts of the body, although no research into the functions of the *cortex cerebri* shows any trace of an emotional center there. Nor need we be surprised, if we are at all prepared to believe the truth known to every lover of animals — that they have emotions like our own. The emotions must have their central seat in some old-established part of the brain. The Italian student Pagano has added much evidence in favor of the view that the "basal ganglia" of the brain, the great and ancient masses of nervous matter which occupy the base of the cerebrum, are the seats of the emotions

And now we come to the simple but all-important question, What is the true relation of emotions, which are supposed to occur in man (because he knows he feels them), and instincts, which are supposed to be the peculiar characteristic of the lower animals?

Emotion the subjective aspect of an instinctive action

The truth, as Dr. McDougall was the first clearly to perceive and to prove, is that no such distinction as is commonly asserted exists at all. The facts are just the same in a man or in a dog. We can see inside ourselves, we have first hand knowledge of our own consciousness, and introspection instantly detects what we call emotion there. We cannot see or feel the emotion of a dog; we only see its instinctive actions. As for our own actions, they are so largely modified in character by our intelligence that their fundamentally instinctive character is commonly overlooked. Now, we have only to put two and two together. Man has emotion and instinct, and so has the dog. In both the emotion is simply the subjective, internal, psychological aspect of the objective, external, physiological performance or process which we call an instinctive action. But the two are really one and the same thing, with its double aspect; and henceforth they must be studied together, for they are inseparable, and neither can be understood without the other.

This theory of emotion as simply the "affective" or "feeling" side of instinct has now definitely superseded the James-Lange theory of emotion and all others. It was first briefly stated by Dr. McDougall in 1905, though, as he points out, William James and others came at times very near to it.

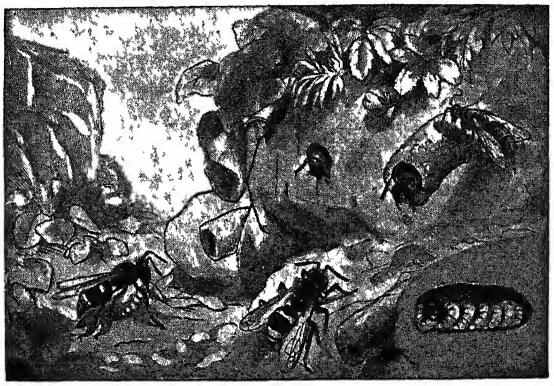
Probably Dr. McDougall's advantage lay in his biological and medical training, which made it impossible for him to accept such distinctions between the fundamental facts of, say, man and the dog, as we have already quoted and repudiated In very terse but complete form, the theory, as later defined by its author, runs as follows: "Each of the principal instincts conditions, then, some one kind of emotional excitement whose quality is specific or peculiar to it; and the emotional excitement of specific quality that is the affective aspect of the operation of any one of the principal instincts may be called a *primary emotion*."

Directly we apply this theory it works like magic. At once we can begin to form great pairs of instincts and emotions which largely dominate the life and constitute the mind of man — the instinct of flight and the emotion of fear, the instinct of repulsion and the emotion of disgust, the instinct of curiosity and the emotion of wonder, the instinct of pugnacity and the emotion of anger, the parental instinct and tender emotion, and more besides. These are the real architects and constituents of man, of his behavior, his institutions and his societies.

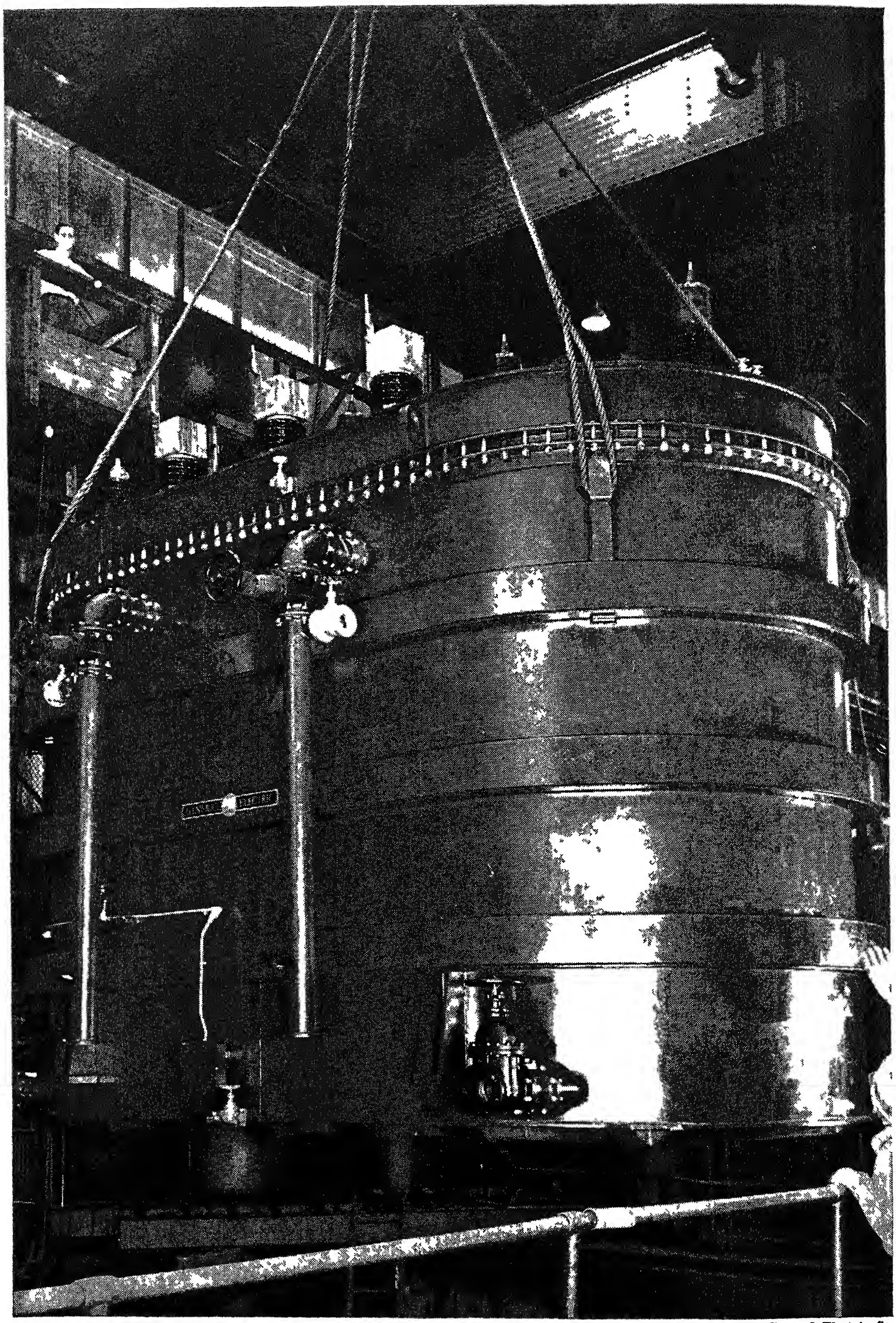
He may call himself the reasoning creature, if he will, and, in so far as his intelligence is almost or quite his most distinctive characteristic, no doubt he is entitled to do so. But if he thinks that his intelligence moves him, is the spring, the motor of him, he talks nonsense. It is merely an instrument, used in the service of the instincts, just as habits are formed in their service "Mankind is only a little bit reasonable, and to a great extent very unintelligently moved in quite unreasonable ways. By all means let us be moved in only reasonable ways, but, even so, reason is not the mover. In truth, men are moved by a variety of impulses whose nature has been determined through long ages of the evolutionary process without reference to the life of men in civilized societies."

The problem for mankind is not, as many Eugenists suppose, to get more "ability" into the world The problem is to adjust a creature such as man, moved by his instincts for what, in our moral judgment, we call "good" and "evil" both, to the needs of social life, and to the demands and the restrictions, the gains and perhaps the losses, which that implies. The tragedy of the world is not the lack of ability, which is merely power, like dynamite, but the terrible "disharmony", more serious than anything Professor Metchnikoff writes about under that name, between the various instincts of any man, and only too often between their upshot in conduct and the highest needs of mankind.

If these supreme and colossal problems are ever to be solved — which has been the task of society, of religion and law, and custom and institutions and government in all ages — we must seek ever deeper and truer understanding of its factors within the instinctive and emotional nature of man. Therefore it is to closer study of the greatest of these factors that we must now proceed.



MUD-WASP INSTINCTIVELY PREPARING FOR ITS PROGENY



General Electric Co.

Hoisting a powerful 150-ton transformer, which will raise 15,000 volts of electricity to 135,000 volts.

POWER OVER DARKNESS

The Battle between Gas and Electricity and the Marvels of Modern Illumination

THE CHEAPENING OF ARTIFICIAL DAYLIGHT

SO great a power has man already obtained over the gloom of night, that if the electric furnaces working at Niagara Falls were combined into one white glow, the radiance could be seen from the moon. Possibly the whole electric power obtainable from the vast waterfall might be transformed into a signal fire that would be visible from Mars.

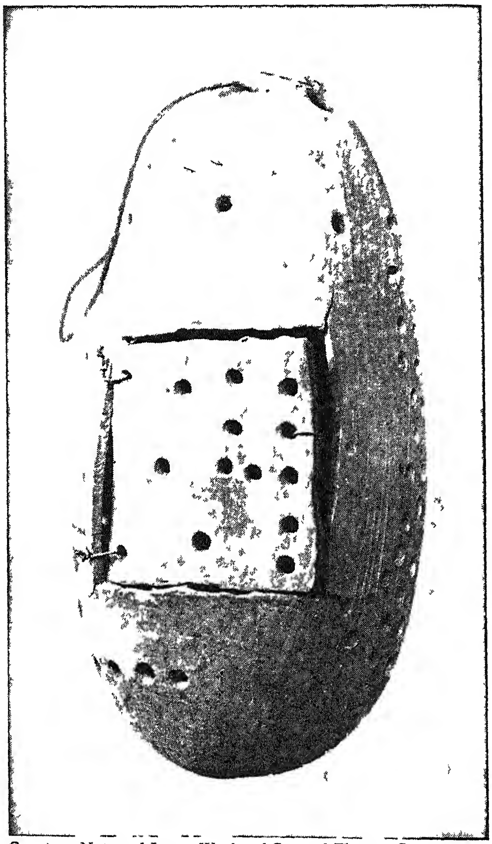
Yet a hundred and fifty years ago the civilized races scarcely had any stronger means of overcoming darkness than those possessed by savage and barbaric peoples. In the days of Shakespeare the lighting of both palace and hovel was exceedingly primitive. The guttering of rush lights, and the splutter and smell of faint lamps fed with animal fats, made a court festival at night a dim and not altogether pleasant affair. Indeed the world could show but little advance upon the methods of lighting invented by some ingenious cave-dweller of the Age of Stone. He used a small, shallow lamp, filled with animal fats, in which was placed a bit of dry wood or a wisp of grass that served as a wick. Even the Romans, in the days of their power, had a somewhat similar lamp of burnt clay, holding a little fish oil or animal oil. Our forefathers hunted the whale chiefly for lamp oil, and many of our coast towns owed their early prosperity to their being centers of the sperm oil industry. The Chinese, from time immemorial, had kept their picturesque lanterns alight by means of oil crushed from vegetable seed; but it was only towards the middle of the eighteenth century that colza or rape-seed oil, obtained from the wild cabbage, began to be largely used for lighting purposes.

The lamps, however, in which the new oil was burned remained quite primitive in construction until Aimé Argand, a Swiss, discovered a way of supplying air both inside and outside by means of a hollow burner into which a tube-shaped wick was fitted. The increased supply of air to the burning flame brought about a stronger and quicker combustion, with the result that the light became clearer and brighter.

It is impossible to understand the frame of mind and the social condition of both the savage and civilized races of the past unless regard is had to the feeble power over darkness that the whole of the human race then possessed. When this planet of ours turned away from the light of the sun, and swung out into the mystery and darkness of interstellar space, strange and horrible powers seemed to sweep in upon the earth. Anybody who as a child has walked alone along a dark country road on a windy night will remember the primitive superstitions that then assailed him. Ghostly forms crouched amid the bushes, uncanny things whispered and moaned and glimmered in the fields, the trees and the hedgerows. These fears of the night have always haunted man. Most probably they were based at first upon the terror of nocturnal beasts of prey; but when the early savage discovered a method of guarding himself from bodily enemies by means of a camp-fire, lighted with a fire-drill or sparks from a flint, the awful gloom around him still worked on his mind and imagination, so that he peopled the darkness with spirits of dread and horror.

This extraordinary superstitiousness in regard to the imaginary terrors of the night

has been responsible for much of the delay in the evolution of the clear, rational constructive powers of the human mind. Men were fairly reasonable in broad daylight, but when night fell their primitive fears awoke, and the old superstitions resumed somewhat of their ancient sway over the imagination. It is not very long since the traditions of the dark ages entirely lost their power over the minds of



Courtesy National Lamp Works of General Electric Co

UTILIZING THE SECRET OF THE FIREFLY

The West Indian native illuminates his pathway by a perforated gourd filled with hundreds of fireflies

the larger number of civilized people. Even Francis Bacon, the apostle of experimental science, believed in the existence of the evil spirits of darkness, and looked upon them as legitimate objects of study. It is not too much to say that the greater part of the cruel, sanguinary mind-deadening practices and ideas in primitive and pagan religions were engendered by man's terror of darkness.

Probably there have never been wanting bold criminals who, playing on the general fears, used the darkness to do wrong to their fellow-men. Only by bearing in mind how ill-lighted were the streets of European cities in the eighteenth century, and how dark and deserted were the towns and villages on the country roads at night, can we understand the social conditions under which the footpad and highwayman pursued their nefarious business practically unmolested. Even important city thoroughfares were avenues of gloom. The few dim street-lamps that occurred at intervals were merely put up as guides to enable the belated wayfarer to find his way from point to point.

From the earliest times the existence of inflammable gases escaping from the bowels of the earth was known, and, as early as 1739 a paper was presented before the Royal Society describing the production of a similar gas by the combustion of coal in a closed vessel. But it was not until 1792 that William Murdock, a Scot, demonstrated the value of coal gas as an illuminant by lighting his house and office in Cornwall. He moved to Birmingham in 1798 and there lighted the Soho foundry with coal gas. This successful experiment did much more than provide a new luxury for the civilized world. It was one of the greatest advances ever made in discouraging and preventing crime. Light is cheaper than the police.

There are other inventions, such as the railroad, the steamship and the telegraph, which have had a great effect upon economic conditions of the world. But the discovery of cheap and abundant sources of powerful artificial light has removed one of the chief opportunities of the criminal. It has saved the sailor from shipwreck and the railroad traveler from collision. It has turned for many a worker the short, dark days of winter into as prosperous a period of employment as the long, bright days of summer. And it is artificial light of great intensity, used in the microscopic examination of microbes, that has helped to defend mankind against the germs of disease, and illuminate some of the subtlest problems in other branches of science.

So we must put these, and other advantages obtained from an increasing control over the artificial sources of light, against the modern follies of the luxurious class that turns night into day, and against the blinding misuse of electric lights in garish, revolving advertising signs. It is quite true that we are now living in an age of glare. Even in many private houses artificial light is abused rather than used. It is possible that more eyes are now weakened by the employment of too strong and dazzling an illumination than by poor and feeble lighting. But a new class of professional men — the illuminating engineers — are now generally consulted by architects in the construction of every kind of building. They have reduced to a science the relation of light to the human eye, and are able to arrange artificial lighting in a way that makes all work done by it more healthful and more comfortable, with what the reformers contend will be a marked and permanent improvement in the powers of vision in the younger generation.

But the work of the inventors is not completed. No means have yet been discovered of transforming energy into light in a really economic way. The very best of modern lamps, scientifically speaking, is little more than a makeshift. The civilized world is like the Chinese boy in Charles Lamb's fantastic story about roast pig. The boy was the first discoverer of the delights of cooked meat, but his only way of cooking it was to burn down his father's house, so that the pig should be roasted in the flames.

JAPANESE LANTERNS IN A STREET IN TOKIO

Our ways of producing artificial light are almost as primitive. Neither gas nor electricity is yet used in an efficient manner. We take something and make it very hot, though heat is the very thing we do not wish to create. Still we make it very hot often using about 99 out of 100 parts of energy in generating wasteful, unwanted and injurious heat. So we go on until the thing gets white-hot and begins to shine. Then, like the Chinese boy we think we have performed wonders.

This process of producing light by heat is known as incandescence. In the customary electric filament lamps, for instance, an electric current is forced through a metal wire that strongly resists the passage of the electricity. All the energy expended in forcing the current through the wire is transformed into heat, and the wire is made at last so hot that it shines. In an ordinary way the wire would quickly be burned up, just as the wick of a lamp is. But the combustion is prevented by pumping the air out of the glass globe, so that little or no oxygen remains to combine with the metal of the wire and burn it away. In the latest type of electric lamp the evaporation of the tungsten filament is counteracted by filling the glass bulb with an inert non-combustible gas such as nitrogen or argon.

DECORATIVE VALUE OF ELECTRIC LIGHT — A SCENE IN THE FRANCO-BRITISH EXHIBITION OF 1908 WHEN THE CARBON FILAMENT STILL PREDOMINATED

It was mainly due to the work of Thomas A. Edison, in 1878, and J. W. Swan, in 1879, that the incandescent electric lamp was developed into a practical success. Edison first employed a platinum wire, but later had the much happier idea of using a carbon filament. He treated cotton thread with sulphuric acid, and obtained a parchment-like substance which was fairly durable. The modern carbon filament is made from cotton-wool that is first dissolved in some solvent and then formed into a long, semi-transparent thread that looks somewhat like catgut.

In an attempt to find some substance that would endure heating to a higher temperature than the carbon filament, Edison and others began to experiment with various kinds of rare earths, such as thorium and zirconium. But it was found that no mixture of any of these earths and carbon was permanent. So they bent their energies to the task of making the carbon filament lamp a handier and brighter and more efficient means of lighting than the gas jet that had become the common light of the civilized world.

In 1879 Edison gave a public demonstration of his incandescent lamp by lighting houses and streets in Menlo Park, N. J. The *New York Herald* devoted an entire first page to this demonstration and it was found necessary to run special trains to accommodate the crowds. In 1880 the first electric lighting system on shipboard was installed on the *Columbia*. One of its original dynamos is exhibited at the Smithsonian Institution.

For some years the victory of the electric lamp seemed to be inevitable. Year by year improvements were made in the manufacture of the electric bulbs and in the

Wide World

Winding up the mechanism that causes a beacon to revolve. A heavy weight is attached, by means of a steel cable, to a windlass. As the weight drops, it turns the windlass; this makes the beacon turn.

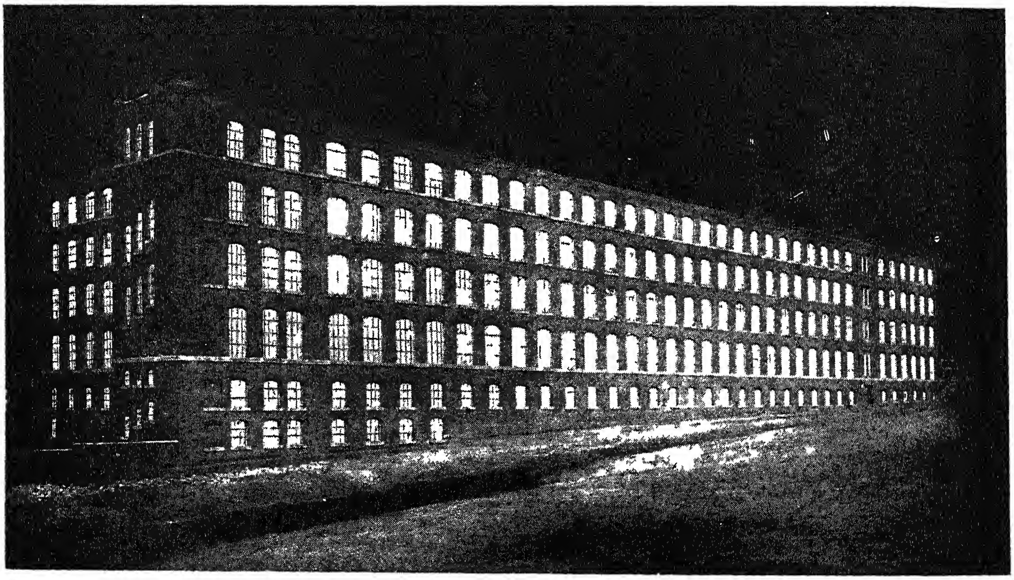
method of supplying electric power in a large way, to private houses and big buildings; and though the powerful gas companies began by ridiculing the new illuminant, the time soon came when electric lighting seriously threatened to displace gas lighting. The cost of gas in the ordinary batswing burner was nearly forty cents for a thousand candle-hours. The early form of glow lamp, on the other hand, produced its light at an expense of under thirty-five cents for a thousand candle-hours. More important still, in the lighting of great buildings and large outdoor spaces, was the progress being made in the electric arc lamps. The closed arc lamp produced light at last for thirty cents a thousand candle-hours, while the flaming arc lamp created the same amount for about five cents.

So matters were proceeding in the battle between electric light and gas light. In the meantime, however, a young Austrian, Auer von Welsbach, took up the study of the rarer earths that Edison had abandoned. He built on a discovery made in 1835 by Captain Thomas Drummond. Drummond knew that the light-giving quality

of gases depended on the carbon brought to incandescence in a flame. For in the absence of carbon, as when a jet of pure hydrogen was burned, extreme heat was produced without any light whatever. Drummond introduced the needed solid body into a burning jet of hydrogen, by means of a block of compressed quicklime. Thus was invented the Drummond lamp of intense limelight still used in theaters.

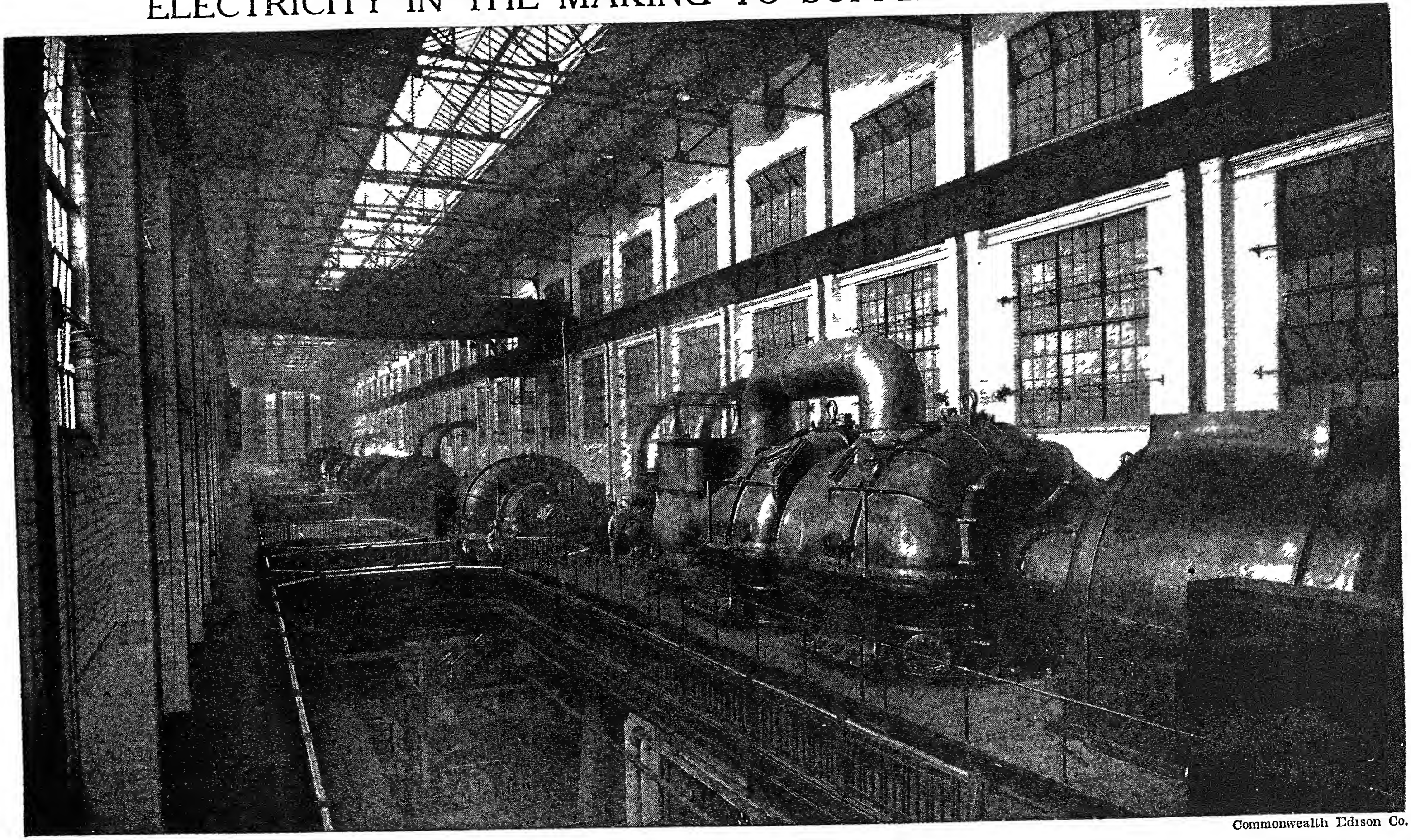
Now, the rare earths resemble lime in their effects upon the radiancy of gas. This was why Welsbach, in 1880, began his researches into the same strange substances as the inventors of the glow lamp had experimented with. In order to ascertain their value as illuminants, the young Austrian chemist brought to melting point one specimen after another of the rare earths on bits of platinum wire. In each case the experiment was remarkably unsuccessful. Little beads of the earths formed on the wire, and instead of improving the quality of the light the beads only dimmed it. Most men would have given up the matter on obtaining this very disappointing result, but Welsbach was inspired by his disasters; and there came into his mind an idea of that golden quality that only an inventor of genius hits on. He saw that the very thing that had made the rare earths unsuitable, when combined with the cotton filament of the electric glow lamp, would be successful in a gas burner For in the gas flame all the carbonized cotton would be quickly burned away, and the rare earths would remain So he wove a mantle of cotton thread, and soaked it in a solution of one of the rare earths, and dried it and put it over a Bunsen gas burner. The cotton at once burned away, leaving a mantle of earth that increased the light-giving quality of the gas in a wonderful manner

The young inventor, however, had not come to the end of his troubles. His marvelous mantles crumbled to pieces in a few days; so he mixed the earth with another substance that would not fall to pieces so easily, and after six years of laborious research and experiment he made a better mantle. The extraordinary efficiency of the new means of gas lighting naturally attracted wide attention Several companies were formed for the manufacture and sale of the mantles. In a year or two, however, all these companies were on the verge of ruin. People at first bought the mantles with eager delight; it seemed that gas had suddenly and completely triumphed over the electric filament lamp. But, unhappily, the mantles were



INDUSTRIAL VALUE OF THE NEW ILLUMINANTS — A FACTORY AT NIGHT AS BRIGHTLY LIGHTED AS BY DAY

ELECTRICITY IN THE MAKING TO SUPPLY A GREAT CITY

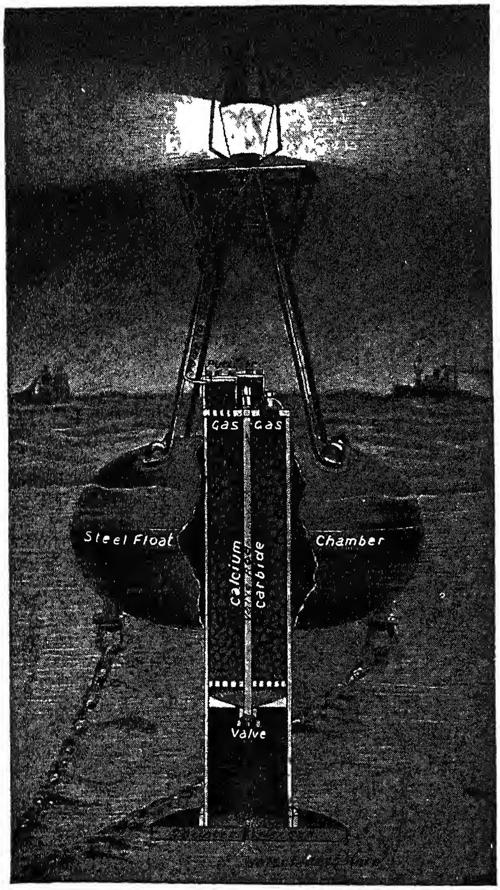


Commonwealth Edison Co.

The turbine room of a Commonwealth Edison Company power station in Chicago. The total power generated in these turbines is 120,000 kilowatts

still very fragile. So numerous and costly were the breakages that the public returned to the use of the new electric light, or contented themselves with the ordinary dim but steady gas flame.

Welsbach vainly strengthened his mantle with new and stronger earths. Business did not develop, and the mantle companies thought of closing down. An



PICTURE-DIAGRAM OF GAS-LIGHTED BUOY

The sea water passes through a controlling valve into a cylinder filled with calcium carbide, and combines with it to form the gas, which passes out through a purifier into the feed-tube of the lamp.

accident abruptly converted them into one of the most prosperous of modern undertakings. At this time Welsbach was using the rare earth thorium in his mantle. Going into a factory, he chanced to find a bit of raw thorium oxide. He set to work on this then scarce and rare earth, in the hope that by purifying it thoroughly he would obtain a substance that would increase the light from the gas mantle. But when the purification process was completed and a mantle made of thorium, the light fell off in an unaccountable fashion. What could be the matter? It looked as though some valuable element had been cast aside in the process of purification. A series of new researches showed that it was a minute quantity of cerium which provided the valuable element.

Here was a discovery of the highest importance. It put a new complexion on the battle between gas light and electric light. As the result of many experiments it was found that one part of cerium and ninety-nine parts of thorium oxide were the best proportions of the earths used in the making of gas mantles. Why these proportions are the best, nobody knows, but the happy discovery of them, in 1890, changed the fortunes of all the gas companies throughout the world. The cost of gas lighting dropped from nearly forty cents a thousand candle-hours to something well under seven cents. This compared very well with the thirty-five cents a thousand candle-hours of the electric glow lamp of the second class and the twenty-five cents cost of the same amount of illumination from the electric lamp of the first class. Gas was victorious.

But the inventors of electric light were not idle. Indeed, Welsbach himself joined their ranks, after bringing his gas mantle to its present perfection. The problem was to find something at once stronger than the carbon filament and more resistant to the passage of electricity. It was clear that a metal was wanted. So men began to throw themselves into the study of rare metals with the same eagerness that they had pursued the study of the rare earths. Welsbach was first in the field with the osmium lamp, which was put on the market about 1899. Osmium is an extremely rare metal, and the filament into which it was made was extremely fragile. Nevertheless, the osmium lamp was about 75 per cent more efficient than the carbon lamp, and soon expeditions were ransacking the world for the metal.

But the failure to make any large

discoveries was not serious, for several years later Werner von Bolton found that the metallic substance, tantalum, could be formed into a filament. Tantalum is available in fairly large quantities, and the new lamp was nearly one-fifth more efficient than the osmium lamp.

Then came, in 1904, the discovery that revolutionized lighting. Alexander Just and Franz Hanaman were laboratory assistants in the Technical High School in Vienna. Just was making use of his spare time by trying to develop an incandescent lamp with a filament of boron, and he soon asked Hanaman to assist him. When the boron lamp proved a failure, the two conceived the idea of producing a tungsten filament.

Tungsten was discovered in 1781, but although the supply is plentiful, it had no commercial value except as an alloy in tungsten steel. For more than a century and a quarter it was known as an intractable metal, existing only as a powder of hard, brittle particles or as a rough, more or less fused mass incapable of being forged or worked.

Realizing the difficulties that faced them, Just and Hanaman tried various chemical treating methods. At length they hit upon two ways of producing filaments of pure tungsten. Of the two the more satisfactory was that in which the tungsten was sintered together. The powder was first mixed with a solution of sugar and gum arabic, and the resulting paste was squirted under high pressure through a diamond die. As it issued from the die, it was caught upon pieces of cardboard in loops. It was then treated so that the sugar and gum arabic were turned into carbon, which was removed by a further treating process, leaving pure tungsten.

Courtesy General Electric Co.

MODERN HIGHWAY ILLUMINATED WITH SODIUM LUMINAIRES

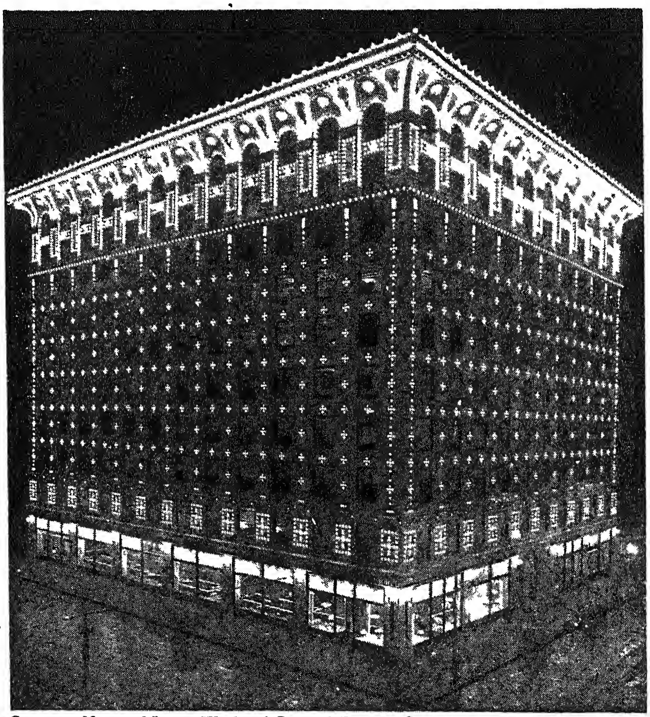
Two years later the tungsten lamp was put on the market. Notwithstanding the fragility of the filament, it was vastly more efficient than the tantalum lamp and was a

great commercial success. But, such are the vicissitudes of modern invention, even the tungsten lamp was doomed.

In Schenectady, N. Y., William D. Coolidge had undertaken to render tungsten ductile. Tungsten could be bent when heated to a very high temperature, but it was as brittle as ever when it cooled. Coolidge, however, discovered that at certain temperatures he could hammer the metal and elongate its cell structure—something no one had ever before accomplished. He used heat-treating bottles and electric resistance furnaces. He pressed tungsten in heated rolling mills used by jewelers, and between hot slabs of tungsten steel. He tried drawing it through heated dies whose diameter was no greater than a thousandth of an inch.

Then, late in the fall of 1908, Coolidge first held ductile tungsten in his hands. For the pressed tungsten filament, drawn through one heated die after another, each slightly smaller than the last, and itself heated and reheated, had lost its brittleness. Verifying his experiments, Coolidge found that tungsten behaved in a manner that was the exact opposite of all other metals. The longer it was worked at high temperatures the more ductile it became, whereas other metals under this process lose their ductility and turn brittle. Peering through his microscope, he found that ductile tungsten was fibrous in structure, while non-ductile tungsten was crystalline—which is also the reverse of all other metals.

But Coolidge's work was by no means finished. Transforming tungsten in a laboratory was a much simpler process than working with large quantities on a commercial basis in a factory. For two years more he kept at the job, and finally he achieved victory by hot-swaging (pounding by hammers while the metal is hot) the tungsten slug. This permitted him to work the slug into smaller and smaller diameters, until, shortly before it reached the die-drawing diameter of 25 one-thousandths of an inch, the tungsten became ductile. Coolidge's success, marking the greatest development in the lighting field since Edison invented the incandescent lamp, was announced in March, 1910. One year later, the new lamps were put on the market.



Courtesy National Lamp Works of General Electric Co

THE ILLUMINATION OF AN OFFICE BUILDING IN DENVER

This is called "the best lighted building in the world."

Drawn tungsten wire filaments were not only much stronger than pressed tungsten filaments, but they were also much cheaper, so the use of the new lamps increased enormously Furthermore, because ductile tungsten could be drawn to such an exact diameter and cut to the desired length so accurately, practically all the lamps made were of the voltage and efficiency for which they were designed Thus it became practical for all power plants to adjust their voltage to one of three standards—110, 115, and 120 volts.

In 1909, while Coolidge was still working on the application of ductile tungsten to incandescent lamps, he was joined in

Schenectady by Irving Langmuir. The newcomer, who later became the first member of an American industrial laboratory to receive the Nobel award, immediately undertook to discover why lamp bulbs sometimes showed on their inside surfaces a blackening that interfered with illumination. He established the fact that there were five gases in the supposed vacuum and that, of these, water vapor was the only one causing any trouble. Yet even when he raised the vacuum from a millionth of an atmosphere to less than a billionth, the blackening continued. Why? He could think of only one other possibility—the evaporation of the tungsten itself.

A succession of experiments proved he was correct: the tungsten filament did lose weight, and the water vapor facilitated the process. But the other gases retarded or even nullified the rate of evaporation. Langmuir thought there might be one gas which would so reduce the rate of evaporation as to increase the efficiency of the lamp.

With the first experiments, however, a new situation arose. He succeeded in retarding the evaporation of the tungsten, but the dissipation of heat from the filament through gas conduction was found to be considerable. Some gases cooled so rapidly that the amount of electrical energy required to maintain the proper filament temperature made them commercially impractical. Now the problem was to determine what combination of inert gas and tungsten filament would reduce the evaporation of the tungsten and overcome the dissipation of heat through the gas.

Investigating, Langmuir discovered that, when heated in any inert gas, a filament became surrounded by a film of hot gas. This film had a thickness independent of the diameter of the filament. If the filament was doubled in size, the film became only slightly thicker and the rate of dissipation did not become doubly greater. It was obvious that filaments of larger diameter would be more efficient in gases. This, unfortunately, meant a larger quantity of raw material in the filament.

Langmuir continued his experiments until he had satisfied himself that argon was the most desirable inert gas for the lamp bulb. He also found that the gas should be introduced at atmospheric pressure, rather than in a high vacuum. But the lamps he made for testing contained large filaments and consumed several thousand watts.

One other question remained to be answered: was it impossible to use a filament of small diameter? Langmuir found it was not—a coiled filament of small diameter gave all the advantages of one of larger diameter.

Here at last was the light the world had been waiting for. It was twice as efficient as the ordinary vacuum tungsten lamp, fourteen times as efficient as the first carbon lamps.

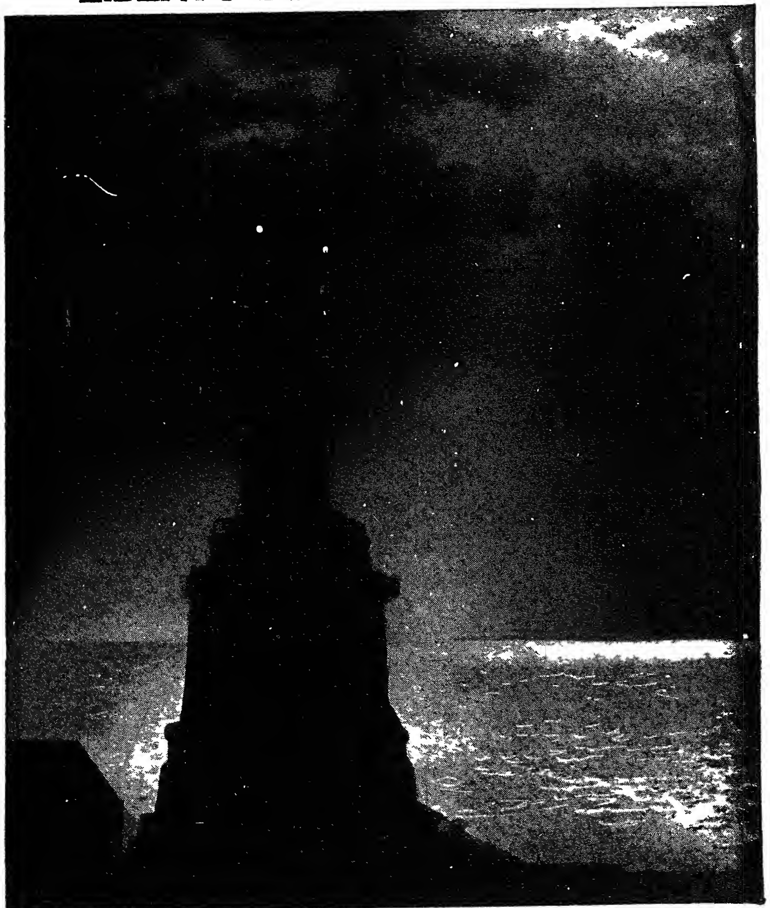
Today, an incandescent lamp is even more efficient than the Langmuir lamp introduced in 1913. Indeed, a modern 60-watt lamp gives as much light as a 100-watt lamp did only twenty years ago. Yet, despite improvements, it is much cheaper. An early 60-watt carbon lamp cost $1.75; one today costs only 13 cents.

While these developments were taking place, comparable advances were being made with other types of electric light. In 1746, Bishop Watson produced the first electric light—a beautiful arch of flame between the points of a U-shaped tube. In 1801 Humphry Davy made an arc between two carbon poles. In 1870, when Zénobe Théophile Gramme brought out his famous dynamo, the arc lamp was here to stay, for it then became easy to produce light by sending a steady and powerful current leaping across one carbon point to another.

The earliest practical arc lamp was the so-called open arc, because it was exposed to the atmosphere. This was improved by adding an enclosing globe round the arc. Then came the flaming arc lamps—open and enclosed—using carbon electrodes, either impregnated with certain salts which add luminosity to the arc, or with cores which contain the required material. Finally, the amount of light from the arc was increased still more by the use of electrodes of magnetite. But because of certain technical characteristics, the lamp was used almost entirely for street lighting.

Although most people would probably

LIBERTY BY PALE MOONLIGHT



© International Film Service
The Statue of Liberty in New York Harbor as it appeared for thirty years, illuminated at night only by moonlight

LIBERTY BY ELECTRIC LIGHT

Courtesy General Electric Co
The Statue of Liberty after it was illuminated at night by a battery of flood-light projectors.

PUBLIC UTILITY BUILDINGS THAT GLOW AT NIGHT

Photo Eugene Taylor

New Building of the Southwestern Bell Telephone Company, St. Louis.

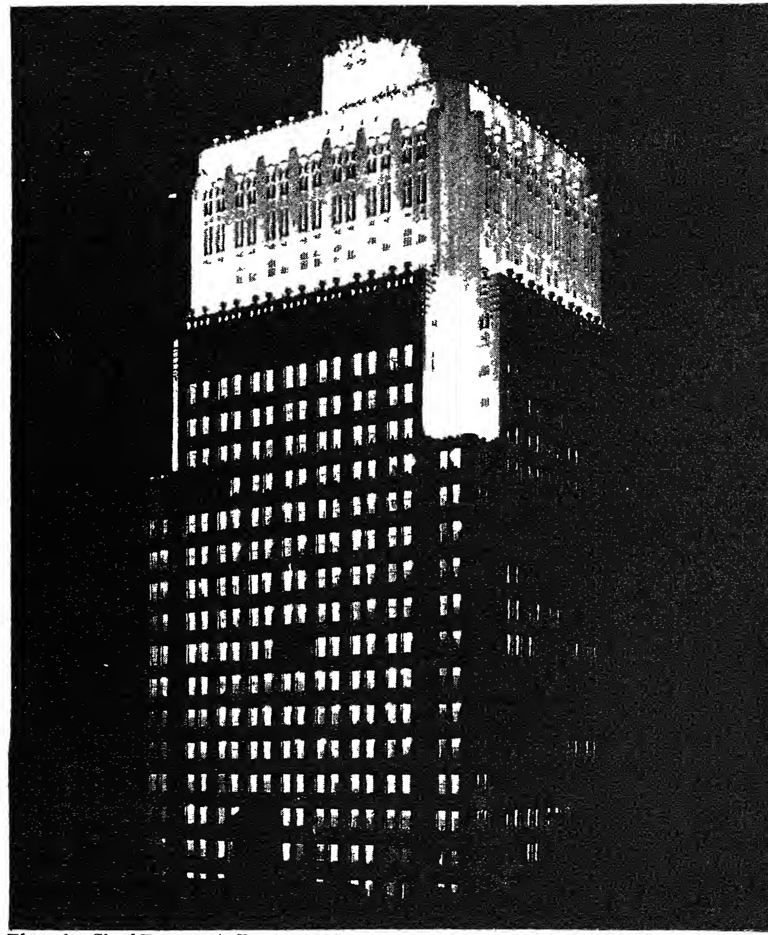


Photo by Chief Engineer's Dept.

Pacific Telephone & Telegraph Company's Building, San Francisco

have been satisfied with the incandescent and arc lamps, scientists have felt otherwise. Their chief worry arises from the fact that so much electric energy is wasted in the production of undesirable and unusable heat. But over the years they have learned how to correct this situation by the development of electric discharge lamps which give off a soft, diffused and remarkably "cool" light.

Without delving into the more theoretical aspects of these lamps, it will suffice to say that almost any of the elements, if introduced in a gaseous state in a lamp, will produce light of some characteristic color. Mercury, sodium, and neon are the elements most widely used.

In electric discharge lamps, electrons are forced out of their normal positions in the gas atoms and produce radiations which, in turn, produce visual sensations in the eye. Various gases may produce this sensation entirely in a particular color band. Neon, for instance, is red; hence, the popularity of neon lamps for use in signs. Others produce various color sensations depending upon the gas pressure.

One of the most familiar of the electric discharge lamps is the sodium vapor lamp, which gives light in the golden yellow range. The bulbs contain small amounts of metallic sodium and neon gas. The latter is used for starting, and accounts for the redness of the light when it is first turned on. But once the lamp is operating, the yellow of the sodium becomes predominant. The high efficiency of the light has made it very useful for lighting streets and highways. A particularly outstanding installation is that on the San Francisco-Oakland Bay Bridge.

A second lamp of this family is the mercury-vapor lamp, invented by Peter Cooper Hewitt and brought out in 1902. The original model was efficient but distorted colors because of the absence of red rays. Although this defect was partially corrected in later models, lack of certain colors and need of special equipment have discouraged installation of the lamps in homes. In factories, offices, and stores, however, where sharp contrast or minute detail must be brought out, the mercury-vapor lamp is extensively used.

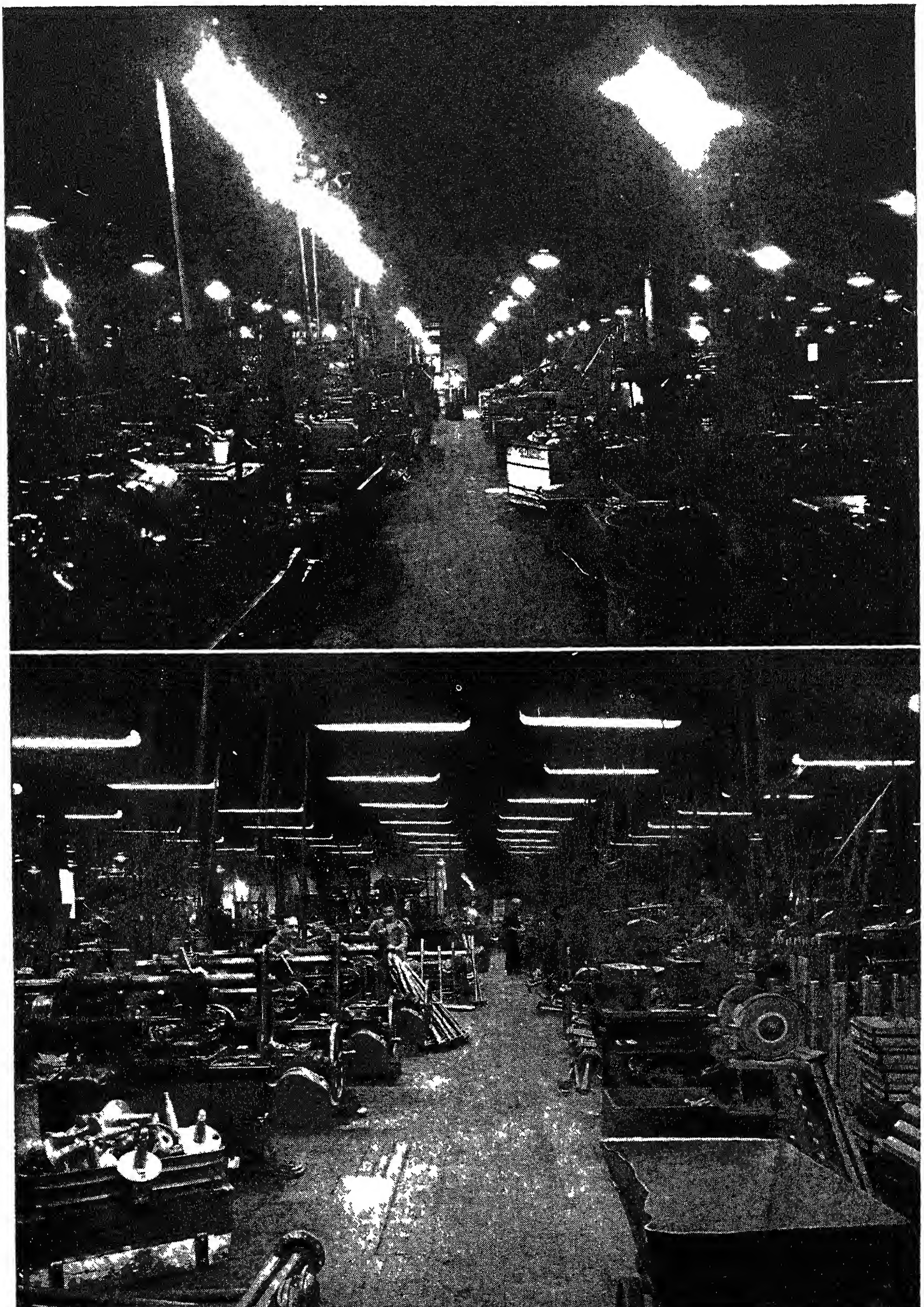
None of these lamps holds as much promise for the future as the newest electric discharge lamp—the fluorescent. The idea of a fluorescent light source has long been in the minds of scientists, but it was not until 1935 that actual developmental work was started. Then, after three years of intensive research, the General Electric Company finally introduced the lamp.

This lamp is tube-shaped—from 1 to 1½ inches in diameter, and from 18 to 60 inches long. It is coated on the inside with phosphors, finely powdered substances which have the property of becoming luminous upon exposure to certain radiation. Without this coating, the lamp is essentially a glass tube containing a small drop of mercury and a small amount of argon gas to facilitate starting. The principle is the same as that used in the mercury-vapor lamp. But in the latter case the electrical characteristics, vapor pressure, current density, and voltage are so regulated that the resultant discharge produces directly as much light as possible. In the case of the fluorescent lamp, these elements are adjusted so that the discharge produces very little visible light directly, but does crowd as much energy as possible into the ultraviolet radiation at one specific point. Mercury is used as the conducting vapor because of its high efficiency in the production of ultraviolet radiation that activates the phosphors which are coated on the inside of the bulb.

The explanation of the property of materials which fluoresce under the action of ultraviolet radiation is simply that such materials absorb energy at one wave length and reradiate it at longer wave lengths in much the same manner as a transformer absorbs wattage at one voltage and current, and delivers this power or energy at a different voltage and current. The reradiated energy of the fluorescent powders, however, is spread over a continuous band of visible wave lengths.

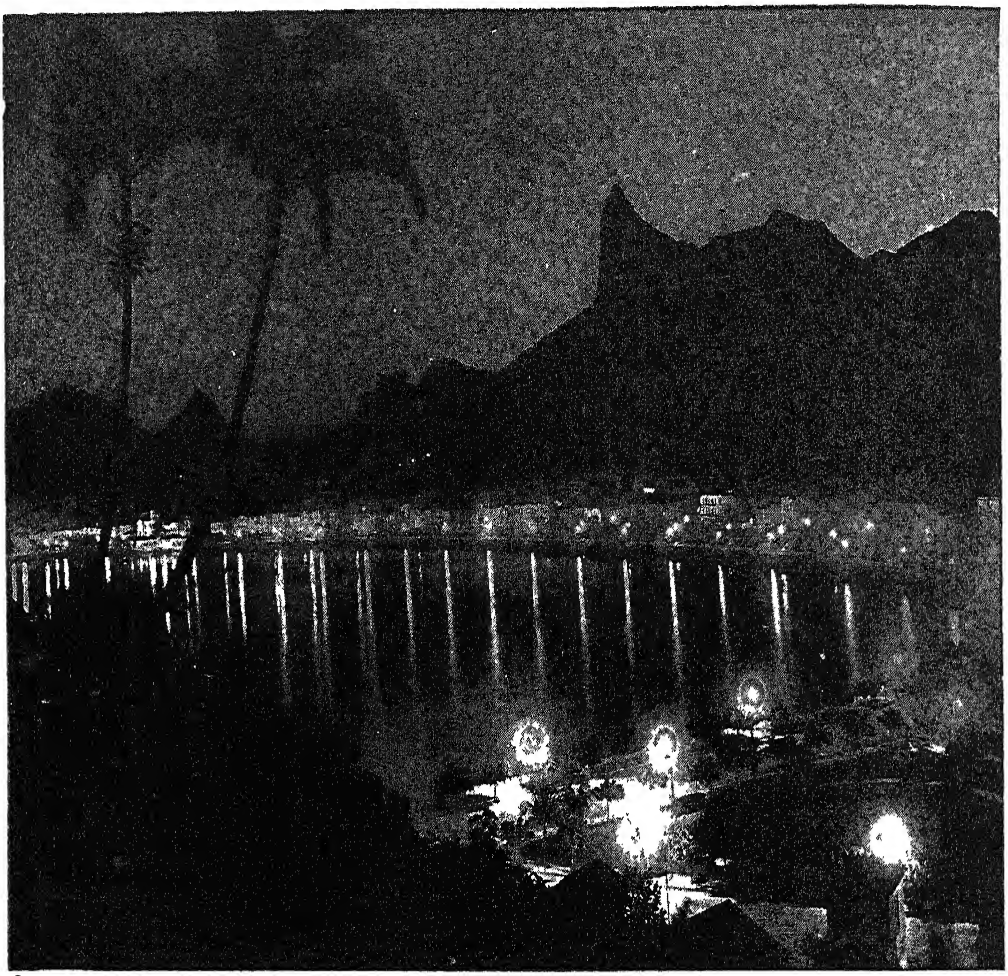
Although fluorescent lamps more nearly resemble the other electric discharge lamps, they are commonly compared with incan-

SUPERIOR LIGHTING WITH FLUORESCENT LAMPS



Courtesy General Electric Co

Above, a war plant lighted with ordinary incandescent lamps. Below, the same factory after the installation of fluorescents.



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THE BAY OF BOTAFOGO, RIO DE JANEIRO, WITH THE PEAK OF CORCOVADO IN THE BACKGROUND

Rio, "the best lighted city in the world", is a fairy scene at night viewed from the encircling hills.

descent lamps. The reason is that, like the incandescent, they can be used for almost every purpose. It may be, therefore, that eventually, when the lighting engineers have learned how to use them most efficiently and when fixtures are designed to accommodate them, they will supplant the incandescent lamps, and perhaps all other types of lighting. For not only can fluorescent lamps be made to emit different colored light, but the light of the "daylight" fluorescent is the closest man has come in approximating the light of the sun. In addition, the fluorescent lamp is very cool, and it gives three times as much light for the wattage consumed as a tungsten-filament lamp of corresponding size.

THE PATHWAY OF OUR FOOD

The Need for Establishing Rules for the Regular, Unconscious Working of the Body's Mechanism

THE PROTECTIVE POWER OF DENTISTRY

FAR more important than most of our discussions about the kinds of food is the proper care of the alimentary canal, which has to deal with the food. If the machinery be in good order it will get value out of almost anything; if it be out of order nothing may be of any value at all. At and in the very mouth of the alimentary canal are the teeth, and a primary condition of health is either to have sound teeth or, at the very least, to have no unsound ones. For the first of these alternatives no prescription can surely avail. Heredity has too much to say in the matter. If we happen to belong to certain of the backward races, we shall almost certainly have thirty-two perfect and unassailable teeth. If our heredity is more fortunate in other respects, it will probably be less fortunate in that. We therefore cannot promise ourselves that the best care in the world will preserve our teeth, or be warned that the utmost neglect will hurt them — "it all depends". We all differ in our chemistry as in our faces. Hence the kinds and number of bacteria that can inhabit our mouths differ also, according to the particular character of the secretions which our mouths produce. Upon this, essentially, the fate of our teeth depends. If they decay, it is because certain microbes produce acids which slowly dissolve the salts contained in the enamel covering of the teeth; if they survive, it is either because the mouth will not allow such microbes to exist in it, or because it produces such alkaline secretions as neutralize the bacterial acids.

There are certain factors at work here which we can only very imperfectly control. But what we can do is eminently worth while doing.

It may be doubted whether the students of the chemistry and bacteriology of the mouth have yet found out the exact agent which destroys our teeth. It is, no doubt, something derived, or often derived, from sugar, though, even so, we know now that one may take abundant sugar and do one's teeth no harm. Probably the finest teeth in the world are those of, say, West Indian negroes, who suck the sugar-cane all day long and every day. Nor are we clear as to what the sugar yields when microbes do attack it — as they doubtless do not in such cases.

One thing is certain, however. It is that no one should permit himself to go about with even a single decayed and uncared-for tooth. The decayed tooth is, as such, a source of danger. We may argue as we will whether it should be removed, or repaired, and whether, if removed, it should be replaced. The one certainty is that it should not be allowed to remain in a state of decay. Scarcely more than a generation ago dental work was looked upon as æsthetic but not much more. The decayed tooth was not seen to matter — at any rate, if it was not seen it did not matter. Now, however, dentistry is recognized as representing a very important phase of preventive medicine. The feeling of physicians at the present time is that the mouth is one of the most vulnerable avenues of the body for invasion by disease.

Chronic affections directly traced to infection of carious teeth

Only those who have been following very recent medical literature will appreciate that there is a series of the most painful disabling and chronic affections, severe diseases of the nerves and joints, the so-called neuritises and arthritises, the origin of which is now traced directly to infectious processes due to carious teeth. The mouth instead of becoming freer from disease with recent developments of sanitary science has become the focus of more and more bacterial processes.

The teeth are considered so important for health that not a few rejections of drafted men during the Great War were made because of conditions within the oral cavity. If the published record of the War Department should do no more than call public attention to this recent development of medical knowledge with regard to the dangers of mouth infections, it will have accomplished much for the improvement of the general health of our generation.

Dental caries is due to microbes, whose chemical products define the odor of the mouth in which they are permitted to thrive. These products tend to be swallowed, of course, and they are to be looked upon as poisons. If a child or an adult has bad teeth, mastication will be imperfect; the food will go, inadequately prepared, into a stomach which is also being poisoned by foul products from the mouth. This is the root-cause of indigestion in hosts on hosts of cases, and their treatment and cure are the simplest things in the world once we grasp their nature, as we usually fail to do. No adult and no child should be permitted to suffer from these risks.

It matters far more than merely in that a clean mouth, containing no foul teeth, protects us from a constant source of blood-poisoning. At any rate, it is enough to know that many cases of ordinary anæmia, with indigestion and all the attendant symptoms, may be cured by the dentist's steel when even the physician's iron fails altogether.

But there is much more to say. The commonest cause of neuralgia and headache, by far and away, is dental caries, especially in the upper jaw. The doctor, if he still exists, whom you consult for neuralgia, and who prescribes phenacetin or such drugs, while neglecting to examine or inquire after the teeth, is a man to be shunned as irresponsible or incompetent. No one must touch drugs for headache or neuralgia until the dentist has discharged him — and not then.

The openings offered to infection by decayed teeth

But the blood-poisoning, with its anæmia and indigestion, and the neuralgia, are still the least of this question. The most important fact about a decaying tooth is that it is an invitation to infection. Valuable and alive though the tooth is, it is not a vital organ. If the microbes that enter it merely stayed there, we should only have the tooth, at worst, to regret. We know, of course, that they sometimes go further, and then one has a gumboil. These are very "trying", but not very serious. Occasionally the bone of the jaw may itself be attacked, or an abscess may form within the cavity of the upper jaw. Care of the teeth averts these more or less obvious risks, but modern pathology raises entirely new considerations.

The healthy body is well protected against microbes. No microbe can pierce unaided the outer layer of the skin. Probably the same is true of the lining of the mouth, and the surface of the healthy tongue and tonsils. The hydrochloric acid produced by the healthy stomach is a splendid and invaluable antiseptic. Risk begins with a *breach or degeneration of surface*. This may be minute, even microscopic, for so are microbes, but it makes all the difference. Thus in our study of the routes of infection, above all of tuberculous infection, our search begins to be narrowed down. We most of us swallow millions of tubercle bacilli in our milk, but they perish in the hydrochloric acid of the stomach. Yet certainly the bacilli in milk do gain entry to our bodies, and especially to our children's.

Where signs may be seen of the entry of infection

Over and over again the infection shows itself in the neck. Why should the glands of the neck suffer so much, and whence does the infection reach them? Why, also, should the apex of the lung, its highest point, be so commonly the first to be infected in consumption? The answer is that we do not properly guard the portals of the body. The healthy mouth, nose and throat can take care of themselves, and of us. But the decayed tooth will convey the microbes of tubercle readily, by means of the lymphatic vessels, to the lymphatic glands in the neck, and to the lungs themselves. The diseased throat, crowded with adenoids, and with swollen, futile tonsils, is a further invitation.

If you want to keep dangerous people out of your house, you shut the door. The door of one's bodily house has to be opened, to eat if not to speak, and enemies are constantly admitted in this fashion. But what could be a more elementary precaution than to see that no morbid openings lead from mouth and throat into the body itself?

It follows that the value of good dentistry can scarcely be overrated. The contrast between good and bad dentistry is at least as marked as in any other profession, and the best dentistry of today is extraordinarily good. One would require to be very poor indeed in order to be unable to afford the fees of a first-class dentist, for the possession of good teeth, or, at least, the non-possession of decaying teeth, is a *sine quâ non* of health. The cost of the good dentist's work has to be reckoned as against the amount of life which it provides for us. Further, the good work endures, as bad work does not.

The deterioration of teeth partly a consequence of unnatural diet

But the savage and the dog need no dentistry; and when we ask why we should, it has to be admitted that our teeth are not what they should be. There is something to be said for the view that our tendency to dental caries is inherited. Time was when the possession of good teeth must have had some value in the struggle for existence. Those who had bad teeth would tend to disappear. But dentistry and modern cooking have reduced the importance of naturally good teeth so much that many people with naturally non-resistant teeth now survive and have children like themselves. At any rate, there is no doubt that cooking, and the selection of food, in modern days have interfered with the need for thorough and natural mastication, and that the teeth are thus deprived, in early years especially, of the exercise and ample blood-supply which they require.

There is no doubt, then, that, in the discussion of dental hygiene diet is the first thing to discuss; and we should not start out with toothbrush and dentifrice until we have duly considered first questions first. The toothbrush follows. But there are right and wrong ways of using a toothbrush. The mere motion of the brush from side to side chiefly cleanses the flat surface of the teeth, which is least in need of attention. The proper motion is up and down, so as to clear, as far as may be, the spaces between the teeth. Fortunate are those people in whom these spaces are considerable, so that nothing can long lodge in them. One should use the brush almost after the fashion in which a razor is stropped, that is, with a rotation, so as really to do the essential thing, which is to *clear crevices*.

The proper uses of small toothbrushes and simple dentifrices

The brush should be small, it should not be very soft, for such a brush may simply squeeze material into crevices, nor very hard, except for very fine, hard teeth. The injudicious use of too hard toothbrushes, with side to side motion, and with a gritty dentifrice, is apt to wear away the enamel, especially on the exposed aspect of the eye-teeth; and that is the very last end for which one uses a toothbrush.

The requirements of a dentifrice are simple enough, and very definite. There are many pleasant antiseptic fluids on the market, no doubt desirable as mouth-

washes, but they do not have the first necessary qualification of a dentifrice, which is that it should be solid. It must be a powder with a mechanical action, but it must be entirely incapable of scratching the teeth; it will be antiseptic, of course; and it will be alkaline, thus supplementing the action of the alkaline saliva in neutralizing the acids of microbic origin which cause dental caries. A half-and-half mixture of carbolic tooth-powder and powdered chalk serves very well. This is quite cheap if one has the sense to do the mixing oneself, and to buy the ingredients in large quantities. The addition of a little bicarbonate of soda (baking-soda) to the water in the tumbler when one brushes the teeth at night is also highly to be recommended. This antagonizes the destruction of the teeth along the edges of the gums.

Impaired physical condition of school children largely due to unsound teeth

Lastly as regards children, it has been found that the serious septic complications of scarlet fever are much more common and severe in cases where the teeth are bad; that the children with the worst teeth are unhealthy in appearance, and below the average in weight, and nearly always below the average as regards their school-work in proportion to their age.

An English authority, reporting to the British Dental Association, calls attention to the fact that: "The mental and physical development of the children attending the public elementary schools is much hindered by the wholesale neglect from which their teeth are suffering; their susceptibility to diseased conditions is much higher than it would be if their mouths were kept healthy; and, moreover, should they be unfortunate enough to contract scarlet fever, the probability of their suffering from one or other of the serious complications that frequently follow this disease would be considerably increased. In short, the prospect of a child deriving the full benefit of the instruction provided in an elementary school is much impaired by the prevailing condition of the teeth."

In America great efforts have been made to correct this. A system of physical examination of school children is now in operation in more than 400 of the cities in the United States. Nurses have been appointed to assist doctors in their examinations and direct the children to free hospitals and clinics. In the great Forsyth Dental Institution at Boston 200,000 treatments can be given annually.

Constipation the commonest malady due to modern abnormal conditions

We are responsible for the care of our teeth, and then for the care of the bowel. Numerous and complicated processes intervene, but they are, fortunately, beyond our control, and in no need of our supervision. We do our duty to ourselves, or those for whom we are responsible, if we attend duly to the diet, to mastication, to the teeth themselves, and to the bowel.

The abnormal conditions of our lives are responsible for the attention which so many people require to pay to what should require none. The careful selection of our diet, its careful preparation (all directed towards reducing the quantity of "ballast"), together with our too-often sedentary mode of life — which means that the muscles both of the abdominal wall and of the abdominal organs tend to lose their tone — these combine with the hurry of our lives, making us feel that we must get on to our work the instant after breakfast, so that, in the upshot, constipation is established as by far the commonest malady of the civilized world. Notable testimony to this fact, familiar to all general practitioners, is furnished by the analysis of patent medicines. They are consumed to an amazing extent, and by far the greater part of all of them simply consists of aperient substances.

The mischief that follows from using aloes as a regular aperient

The standard stimulant of the lower bowel. which is aloes, is *the* constituent of the most popular pills and syrups, and so forth. These drugs must not be condemned outright; they are, of course, absurdly expensive, but that doubtless

helps, in an unsophisticated world, by providing or fortifying the element of faith or auto-suggestion, which tells powerfully upon the action of the bowel. But they do effectively relieve the constipation of hosts of people; and if their use were strictly occasional, there would be little need for criticism. On the other hand, the action of aloes is too much confined to the lower bowel, and it largely acts by causing congestion of the veins, which is often apt, in predisposed persons, to lead to the development or aggravation of "piles", or hæmorrhoids. No one, therefore, should take aloes in any form as a *regular* aperient. For that purpose, if, indeed, any medicine is to be employed — and no medicine is necessary for the purpose in those who properly regulate their diet — we require a blend of drugs, so as to act gently but equably on the upper as well as the lower part of the bowel.

The importance of constipation, we need hardly remind ourselves, is not mechanical, but chemical. Microbes appear in the bowel of the infant about the tenth or eleventh day, we are told, and thereafter they are never absent. If the secretion of the kidneys be carefully examined, we can readily find in it, in cases of constipation, toxic substances which we can prove to have been formed in the bowel. The proof is absolute, then, that these toxic substances have been absorbed from the bowel, have circulated in the general blood-stream — going, therefore, to the brain, as everywhere else — and have finally been excreted. The theory of auto-intoxication by constipation is thus established.

Dieting needed with advancing life to avoid self-poisoning

This is the key to many of the facts of advancing life in a host of cases. Sir Thomas Clouston, in his book on "The Hygiene of Mind", says on this point: "Vague feelings of organic bodily discomfort interfere with the full enjoyment of life, and mean that the processes of nutrition, and the working of the great internal organs connected with digestion, are not done as well as before, and no longer give conscious satisfaction. This feeling is often connected with a newly developed constipation of the bowels, and with the diminished keenness of the appetite for food." The author goes on to say that these symptoms are due to an auto-intoxication which demands a considerable modification of the diet at this time of life. This modification should take the form of reduction, and it is particularly necessary to control the constipation to which he refers.

Doctors commonly lay down the rule of "once a day" for an adult. Let no one suppose that this would suffice for an infant, or that the figure is in any sense absolute. There are hosts of exceptions, in both directions, to it which are consonant with perfect health. Many people double and many halve this frequency. The diet of the individual is a most important factor. Whatever the habit be, within reasonable limits — and once in two days is probably the extreme in that direction — at any rate there should be a habit, and it should be adhered to rigorously. This means a healthy education of the bowel as far as its subconscious regulation by the nervous system is concerned.

The great importance of establishing regular bodily habits

We have already hinted at the importance of faith in the control of the bowel, and, indeed, there is no part of the body, nor any function, more closely susceptible to nervous influences. The influence of fear is familiar to most people. Now, in these circumstances it is well to establish a sound habit; and while this is easily and quickly done, it is still more easily maintained. In extreme cases of nervous constipation, in persons suffering from neurasthenia or nerve-weakness, actual hypnotic suggestion may often be successfully employed.

But any reader may train himself in this fashion, with the practical certainty of success. The hour, of course, should be after breakfast, when the various movements associated with getting up have begun to wake the bowel from without, and the breakfast has stimulated it from within.

The need for making the use of aperient drugs unnecessary

The smoker, also, has trained himself, as a rule, to be helped by, if not, indeed, to require, his after-breakfast cigar or pipe for this purpose. The hour must be rigidly adhered to, inclination or no inclination. Enough time must be allowed for the purpose. This is often overlooked, especially as the business man usually has little time to spare at this hour of the day. The nervous apparatus may decline to be hurried, and its action may be absolutely arrested by the consciousness of hurry. So are we made. But if a fixed hour is adopted and adhered to, and if a sufficient time is always allowed, the necessary nervous habit can be formed by anyone.

As for drugs, we have already admitted that it is much better to use them than to be constipated, but it is better still not to require to use them at all. Their use costs money; the dose requires to be increased, just as in the case of hypnotics; and very few of those who use them are subtle and careful enough in their choice to avoid doing harm.

The choice of diet with a view to the natural disposal of food

We have repeatedly insisted here that it is absurd and impossible to judge a diet merely by its nutritive constituents, and to assume that one food is three times as valuable as another because it contains three times as much protein, or what not. Such judgments are absurd, not merely because we do not yet know enough about the elements of nutrition, but also because our diet has at least two important functions to discharge besides feeding us. As we have already seen, the ideal diet should also be, or include, an effective dentifrice, as in the case of the lower animals; and our dietetic theories must either be "squared" with the dental need or else we must take very special and artificial precautions regarding our teeth. Secondly, the ideal diet must be so contrived as to provide for the health of the bowel, and therefore we now must make a few notes upon diet from what is thus a third point of view.

The virtues of oatmeal, graham bread, crusts and fruit

For the relief and avoidance of constipation, oatmeal, oat and graham bread, with its bran, are to be commended. Fresh fruits especially are valuable, partly on account of the aperient salts they contain. Everyone should eat some fruit every day. It is valuable for the teeth, for the bowel and for the blood, and it is the ideal fashion in which to supply one's self with water. Fresh fruit is the best, like fresh vegetables and fresh everything else, but, for the bowel especially, stewed figs and prunes are very useful. Recent developments in the commerce of diet have been very favorable to national health. The introduction of the grapefruit, the melon and various berries, the cheapening of the banana, the enormous increase of the trade in canned fruit, and the great extension of the "season" of the orange have all helped.

The value of simple fluids between meal and exercise

Often constipation can be much relieved by increasing the consumption of fluid, especially between meals. Milk is somewhat constipative, and buttermilk may sometimes be substituted. It is highly nutritive, and may have some special virtues. Nothing can be less sensible than the too common custom of taking aperient medicines every day, while consuming large quantities of, say, improperly made tea, containing an abundance of that highly astringent (*i.e.*, literally "binding") substance tannic acid. The combined anæmia and constipation which afflict so many domestic servants are largely due to their unwise diet, their undue indulgence in badly made tea and their lack of exercise. Constipation is markedly opposed by exercise, and especially by those forms of exercise which involve the vigorous use of the abdominal muscles. The reader who follows, in reason, the advice here given can scarcely fail to insure for himself a healthy acting and active bowel, which will safely absorb his food into his blood, and no poisons with it.

THE VERSATILE ART OF PHOTOGRAPHY

How Images Are Produced and Fixed

by

BEAUMONT NEWHALL

WHEN an amateur first begins to dabble in photography, he is apt to be bewildered by the complexity of his new hobby. And yet, in the last analysis, it is based on two simple scientific phenomena:

(1) Light, passing through a lens, forms an image.
(2) Light darkens certain substances.

We take a picture with a light-tight box, called a camera, which has a lens at one end. Light-rays, reflected from the object that is to be photographed, pass through the lens and affect light-sensitive material at the other end of the camera. An image is recorded on this material; it is rendered visible and permanent by treating it with chemicals. The end product is a photograph: a drawing (*graphé,* in Greek) that has been made by light (*phos,* in Greek).

Men found out how to form images by light long before they learned how to render these images permanent by chemical means. The first device for receiving images was the camera obscura (Latin for "dark room"). In its simplest form this is a darkened chamber, with a tiny hole or a lens, through which light is admitted, at one end. The light forms a reversed image in full color on the back wall of the chamber. The camera obscura may range in size from a small box to a room large enough to admit the whole body of the observer.

The general principal of the camera obscura seems to have been known in antiquity and there are several references to it in medieval writings. Leonardo da Vinci described a simple form of camera obscura in his notebook, written in the early years of the sixteenth century. Later in that century a Venetian noble, Daniello Barbaro, constructed a camera obscura in the form of a box, with a convex lens at one end and a piece of ground, or frosted, glass at the other end to receive the image. He viewed the image on the ground glass from outside the camera; he traced the image on thin paper, which was placed in contact with the glass.

The camera obscura was used for copying purposes in this way for several centuries thereafter. It served several other purposes. It made a fascinating peep show, for one thing. Various astronomers used it for observations of the sun. Isaac Newton made his memorable experiments with prisms in a room that was fitted out as a camera obscura.

With the camera obscura, then, men could view images of outside objects; but once the source of light was shut out, the images disappeared. Before further progress could be made in the art of photography, some means had to be found to make a permanent record of those images so that they could be viewed even after the light source or the object itself was no longer available. This problem was solved when men discovered that light, which produces the image in the first place, could also help to make it permanent.

Long before the first photograph was taken in the nineteenth century, men had noted the effects of sunlight upon certain substances. They had observed that their

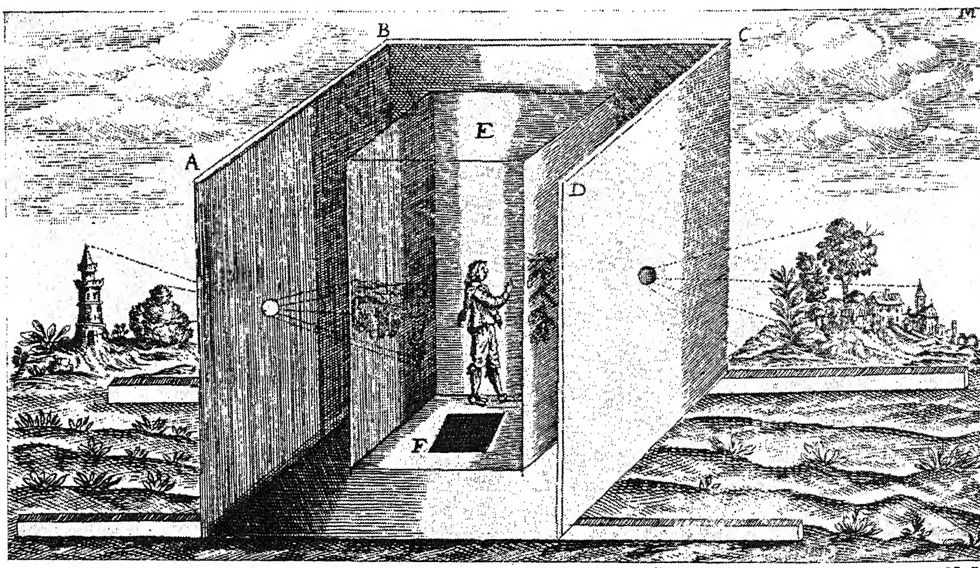
skins darkened in the sun and that the stalks of plants, white under the earth, turned green above ground.

In 1727 the German physicist Johann Heinrich Schulze made a memorable investigation of the effects of sunlight upon silver salts. He filled a glass bottle with a mixture of chalk and silver nitrate. When he exposed this bottle to the sun, the contents turned dark. By shaking the bottle he brought fresh silver salts to the sides of the bottle and the darkening took place again.

Next he cut paper stencils of letters and words, which he stuck to the outside of the bottle. When he exposed the bottle to sunlight, the silver salts darkened but only where the sunlight could actually reach them; the salts that were masked by the paper stencil were not affected at all. After Schulze removed the stencil, the forms of the letters could be clearly seen. He could make the letters disappear again by simply shaking the bottle. These "darkening experiments" paved the way for the permanent recording of images produced by light.

In 1816 a Frenchman, Nicéphore Niepce, put paper soaked in silver chloride inside an improvised camera made from a jewel box and the lens of a microscope. He succeeded in fixing an image upon the paper, but found that all the tones were reversed — that the light areas were recorded as dark tones and the shadows as light tones. In other words, he had produced a negative. Nowadays we begin, just as Niepce did, by making a negative of the object that is photographed. Then, by passing light-rays through this negative upon sensitized paper, we get a positive, in which lights and darks are correctly positioned. Niepce knew nothing about negatives and positives; he felt that the "inside-out" picture he had produced was worthless. Therefore he abandoned his experiments with silver chloride and tried to find a substance that would reproduce the lights and darks of nature in their correct order.

He solved this problem by using a certain kind of bitumen, which reacts rather peculiarly to light. Ordinarily this substance is soluble in oil of lavender; but after being exposed to light, it is no longer soluble in this chemical. Niepce coated a pewter plate with bitumen; he focused the camera upon a subject, exposed the plate and then bathed it in lavender oil. The metal was laid bare only in those areas to which the light had



George Eastman House, Rochester, N. Y.

This is the earliest picture of a camera obscura that is known to the author. It is found in *The Great Art of Light and Shade* by Athanasius Kircher, published in Amsterdam, Holland, in the year 1671.

George Eastman House, Rochester, N. Y.

Daguerreotype of Louis-Jacques-Mandé Daguerre (1789–1851), the inventor of the daguerreotype process. Daguerre was a scene painter.

not been reflected from the subject. He then made these metal areas dark by passing the plate over fumes of iodine. Niepce used this "heliographic" (sun-writing) technique to make copies of engravings. He worked out an ingenious method by which the metal plates were etched so that they could receive ink and could be printed like engraved plates.

While working on this process Niepce made the acquaintance of Louis-Jacques-Mandé Daguerre, a Parisian scene painter. The two became partners in the project of making permanent "light-pictures." Niepce died soon afterward and Daguerre continued the experiments alone. By the year 1837 he had developed what he now called the daguerreotype process. He tried to sell stock in order to finance his new invention, but the public was skeptical. The idea that pictures could be made automatically, without skill of hand, seemed too fantastic to be believed.

Fortunately, Daguerre found a powerful backer in the person of the physicist Dominique-François-Jean Arago, who was both a skillful politician and a first-rate scientist. At Arago's urging the French Academy of Science recommended that the French Government purchase the secret of the daguerreotype process and make it public. The Government agreed; and on August 19, 1839, the secret process was revealed. Lifetime pensions were awarded to Daguerre and to Niepce's heir.

The daguerreotype process consisted of five operations:

(1) A silvered copper plate was brought to a high polish.
(2) It was laid face down on an open box filled with particles of iodine. When the surface became straw-colored, it was placed in the camera and
(3) was exposed, for a time varying from five to forty-five minutes. In semi-darkness the plate
(4) was placed over heated mercury. The image gradually "developed," with the deposit of whitish mercury amalgam in those areas where light had fallen.
(5) To remove the unexposed silver salts, the plate was washed in sodium thiosulfate (then called sodium hyposulfite) and rinsed in water. The treated copper plate was the photograph.

Portraits could not be made with this first daguerreotype process because of the long exposures required: people could not be expected to sit perfectly still for half an hour or so. Obviously the process was very imperfect, and soon experimenters began to improve upon it. They used better lenses; they coated the plate not only with the fumes of iodine but also with those of bromine. They bathed the plate in a solution of gold chloride, which gave it a warm brown tone. The time of exposure was cut down, and portraiture became possible. In the course of the years that followed, many excellent portraits were made by the daguerreotype process.

The daguerreotype was introduced to America in September 1839. Samuel F. B. Morse, the inventor of the telegraph, had

visited Daguerre before the latter's process had been revealed and had become greatly interested in the Frenchman's work. After Daguerre's invention had been made public, Morse began to make daguerreotypes in New York; in 1840 he opened one of the first portrait galleries, or studios, with John William Draper.

When daguerreotyping was in its heyday

Daguerreotyping became extremely popular in the United States; it was probably practiced more widely there than anywhere else in the world. Between 1839 and 1853 over a hundred galleries were opened in New York City alone. Almost every town in the land had at least one "daguerreian artist." Villages and smaller towns were reached by traveling daguerreotypists; one enterprising operator outfitted a floating gallery on the Mississippi River.

Portraiture made up the bulk of the daguerreotypist's business. If a person wanted to have his picture taken, he would go to one of the "operating rooms," as daguerreotype galleries were often called. He would then assume his pose under a skylight at the bidding of the daguerreotypist; an iron rest supported his head. He would remain perfectly still for half a minute or longer, while the exposure was being made. Processing of the plate began immediately after the exposure. Twenty minutes later the customer walked out with a finished daguerreotype, complete with mat, covering glass and neat leather-covered case. The price ranged from two to five dollars.

The daguerreotype was not the only kind of photograph made in the early days. A rival process had been invented in England by William Henry Fox Talbot. He had used a camera obscura for copying purposes; it occurred to him that he might be able to record by chemical means the beautiful images cast on the ground glass of the camera. He now developed a process that he called "photogenic drawing." He published its details on January 25, 1839, eight months before the secrets of the daguerreotype were revealed. Talbot's process was comparatively simple.

(1) Good quality writing paper was soaked in a weak solution of common table salt (sodium chloride) and then wiped dry.
(2) By dim light a 1-to-6 or 1-to-8 solution of silver nitrate was spread on one side of the salted paper. This paper had now become "photogenic" — that is, sensitive to light.
(3) The paper was pressed against a flat object, like a piece of lace or a leaf, in a glass frame or else it was inserted in a camera obscura. It was then exposed to light until a reddish image appeared.
(4) The unexposed silver salts were made relatively insensitive to light by washing the paper with a strong solution of common salt.

Talbot obtained a negative picture in this way; he obtained a positive picture by pressing the negative against a fresh piece of photogenic paper and exposing it to light He made the unexposed silver salts on the second paper insensitive by washing it with a salt solution; later, sodium thiosulfate was substituted for the salt solution. Incidentally, it was Talbot's friend, the great astronomer Sir John Herschel, who first applied the names "negative" and "positive" to the types of images produced by the Talbot process. It was also Herschel who coined the word "photography" to describe the art of making light-pictures.

Talbot discovers the principle of the latent image

In 1841 Talbot found that it was not necessary to leave the paper in the camera until a visible image had been produced. He exposed the paper for a certain length of time and then removed it from the camera. It had apparently undergone no change; but a strong image was brought out when it was put in a bath of gallic acid and silver nitrate. This principle of developing the latent (hidden) image is basic in all photographic processes today. It makes it possible to reduce the time of exposure; an image can be recorded in a

fraction of the time formerly required.

Talbot called the pictures produced by his process "calotypes" (from the Greek word *kalos,* meaning "beautiful") and later "talbotypes." They never became as popular as daguerreotypes. For one thing, images were not recorded so clearly as in the daguerreotype process because of the fibrous texture of the paper that was used. However, some remarkable talbotype portraits were made from 1842 to 1848 by the Scottish painter David Octavius Hill and his colleague Robert Adamson; architectural photographs of great beauty were taken by the process in France and in the Middle East.

In 1851 an English sculptor, Frederick Scott Archer, developed a method for using glass as a negative by treating it with collodion, which is a solution of guncotton. This method resembled the talbotype process, but it required greater skill on the part of the photographer.

(1) A clean piece of glass was carefully polished to remove all dust.
(2) Collodion, to which a halide salt (usually potassium iodide) had been added, was poured over the plate until a uniform film was secured.
(3) In a dark room by orange light the plate was "excited" — made light-sensitive — by plunging it in a solution of silver nitrate.
(4) *While wet* the plate was put into a light-tight holder, placed in the camera and exposed.
(5) *Immediately thereafter* the plate was developed by orange light in a solution of pyrogallic acid,
(6) fixed in a strong solution of sodium thiosulfate or potassium cyanide and
(7) washed in running water.

Prints could be made from the negatives produced in this way by following Talbot's photogenic drawing process. To give greater detail, the simple "salted" paper was replaced by paper coated with albumen, or white of egg; a smooth surface was produced in this way. The prints were invariably toned with gold chloride to produce a rich brown image. This new method of taking photographs was called the wet-collodion process or, more familiarly, the wet-plate process.

It was an unpleasant business, at best. The photographer was chained to his darkroom, because if he delayed in exposing the "excited" plate it would become useless. If he worked out-of-doors, he had to have some kind of portable darkroom. Wagons were fitted out; tents were set up in the field; ingenious trays on tripods were devised with light-tight hoods that covered the photographer's head and shoulders. Despite all these difficulties some of the finest photographs of all time were made by the wet-plate process.

Fine photographs made by the wet-plate process

The French photographer Nadar made the first aerial photographs by this process in 1856. At about the same time Roger Fenton took a van full of wet-plate-process equipment from England to the Crimean battlefields, where he, too, made some excellent photographs. A few years later Mathew B. Brady and his operators used the wet-plate technique in making a remarkable photographic record of the American Civil War.

The wet-plate process resulted in the development of the "calling card" (*carte-de-visite*) technique of portraiture, so called from the size of the finished print. A camera with four lenses made four exposures on one half of a plate; then it made four more exposures on the other half. Of course, each print made from the resulting negative contained eight exposures. The print was cut up into eight small pictures, each about the size of a visiting card. The customer could order a dozen prints for the price of a single daguerreotype; he could also choose the most satisfactory likeness from the proofs of the various poses that had been taken.

The next forward step was the development of the dry plate, which was perfected by Dr. Richard Leach Maddox, an English

amateur photographer, in 1871. He mixed melted gelatin with a bromide salt and added silver nitrate. The emulsion was then spread on a glass plate; when this became dry, it was ready to use. Plates prepared in this way were known as dry plates. The sensitivity of a dry plate to light remained constant over long periods of time; furthermore, it could be developed at any reasonable time after exposure. Therefore, the photographer no longer had to rush into his darkroom with the exposed plate. All that he needed to take with him on a field trip was a camera and a supply of dry plates He could buy these plates fully prepared. Nor was it necessary for him to do his own processing; the company supplying the plates could do the work.

Since the gelatin-bromide dry plate was far more sensitive to light than the wet plate, exposures out-of-doors could be made for the first time in fractions of a second. New cameras were developed that could be held in the hand while such rapid exposures were being made; these cameras dispensed with the awkward and cumbersome tripod.

The year 1888 saw a development that was destined to make photography widely popular. George Eastman of Rochester, New York, put on the market a box camera, called the Kodak, containing a roll of paper coated with gelatin-bromide emulsion A hundred exposures could be made on the roll. When all the pictures had been taken, the camera was returned to the company. The roll was removed from the camera, developed and printed. The camera, loaded with a fresh roll, was returned to the owner together with the prints. The public greeted the new camera warmly; the photography industry soon became big business

The paper negatives used in the original Kodak system were hard to process; the emulsion had to be transferred from the paper support to glass before prints could be made. The idea of using flexible celluloid as a negative emulsion support instead of the heavy and easily breakable glass plates occurred to many experimenters, including a New Jersey minister, Hannibal Goodwin, and George Eastman. In 1889 the latter put on the market flexible film to be used in Kodak cameras and in roll holders that could be fitted to any camera. The perfection of flexible film had an important application; it made possible the development of moving pictures. Thomas A. Edison bought his first motion-picture film

This wood engraving shows a wet-collodion outfit, in use in the field The tent served as a darkroom Within it may be seen the chemicals that the harassed photographer had to carry with him wherever he went

George Eastman House, Rochester, N Y

from the Eastman Company of Rochester.

A new science was now born — sensitometry, the measurement of the effect of light upon photographic emulsions. Two amateur English photographers, F. Hurter and V. C. D. Driffield, working in an attic with homemade apparatus, discovered the basic laws of sensitometry in 1890. Among other things they showed that the development of a plate or a film is controlled by the nature of the developer, its temperature and the time it is allowed to act on the emulsion. It became possible to predict the optimum time of development for any developing agent with any given film. Hasty rule-of-thumb estimates by the dim red light of a darkroom lamp were eliminated. Guess work was reduced; modern photography came into being.

The view camera is still important today

There are many different kinds of cameras in everyday use today. They all fall into one or the other of two groups — view cameras and hand cameras. The view camera is the oldest type of photographic apparatus; it has hardly changed since the days of the wet plate. It consists of an accordion-like bellows of leather or fabric supported by two uprights, which slide on a horizontal frame, set on a tripod or other support. One upright holds the lens and the other is fitted with a ground glass. By putting a black cloth over his head and shoulders, the photographer can see on the ground glass the inverted image formed by the lens. When the exposure is to be made, the ground glass is replaced by a light-tight holder, containing a plate or a piece of sheet film. When view cameras are used in the field, they are set on collapsible tripods. Studio cameras, employed by professional portraitists, are provided with permanent stands, fitted with casters. The latest model view cameras are made of metal, with uprights of extreme flexibility.

The chief advantage of the view camera is that the back may be tipped and the front board that holds the lens may be raised, lowered and tilted. If an ordinary camera is pointed up at a building, the image is distorted; the building appears to be top-heavy. By adjusting the back of a view camera, so that it remains parallel to the building, the distortion can be eliminated. The principal disadvantage of the view camera is that it must be set on a tripod or some other type of support, for it is too bulky to be held in the hands.

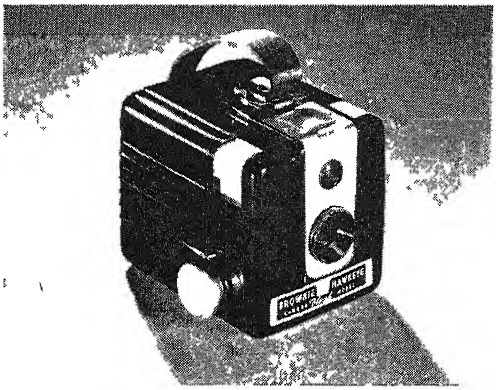
There are many different kinds of hand cameras

The simplest type of hand camera is the box camera. It consists of a box with a simple lens at the front end. It uses a roll of film, wound on a spool; this film is provided with black paper backing to keep the light out when the roll is not in the camera The film is set in position at the back of the camera, with one end attached to a free spool; it is turned by means of a gadget at the outside of the camera so as to expose a certain portion of the film at a time. Eight, twelve or sixteen exposures can be made on one loading of film.

There is a second, smaller, lens in front of the camera The rays of light entering this lens are deflected upward by means of a mirror tilted at a forty-five-degree angle so as to form an image on a small ground glass, called the brilliant finder, set in the top of the box. The image corresponds more or less to the one that will appear on the film; hence the person taking the picture can tell what details will show in the finished picture.

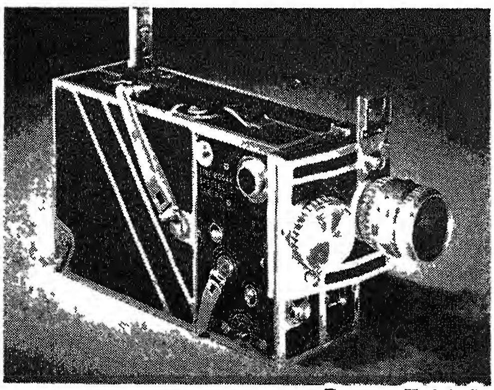
A more compact type of hand camera is the folding model. The lens is fastened to a bellows, made of leatherette or leather, which can be extended for use. The folding model uses the spool method of film loading and is fitted with a brilliant finder. Often there is a direct view finder, a sort of miniature telescope, which makes it possible to hold the camera at eye level.

The reflex camera is quite similar to a view camera except that the ground glass is placed on top of the camera and not at the back. A mirror set at an angle of forty-five degrees within the camera deflects the rays of light entering the lens so that they form an image on the ground glass. In a single-lens reflex camera, the



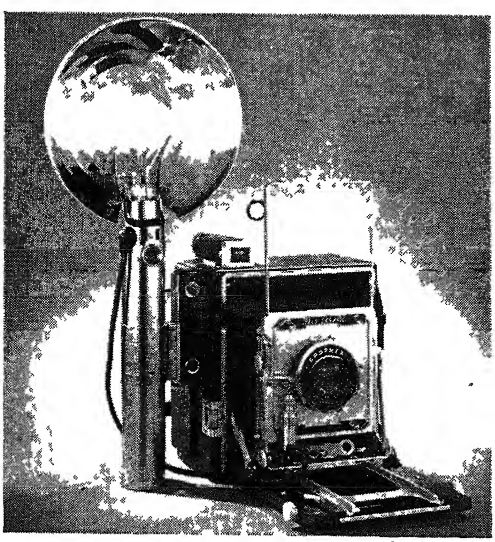
Eastman Kodak Co

The box camera shown here is ideal for beginners



Eastman Kodak Co

This fine moving-picture camera records action



Graflex, Inc

News photographers like this bellows-type model.

film, at the back of the camera, is masked by a shutter, called the focal plane shutter, which can be rolled up like a blind When the picture is to be taken, a lever is pressed. The mirror swings upward; simultaneously the focal plane shutter is rolled up automatically so that a horizontal slit in it flashes past the film, admitting light Since slits of varying widths are set at intervals along the focal plane shutter, various shutter speeds are possible.

The twin-lens reflex is really two cameras in one. One lens forms an image on ground glass and is used only as a finder; the other lens takes the picture. This type of camera differs from the ordinary box camera in that the finder image is the same size as the picture and both lenses are focused together. When the ground-glass image appears sharp, the image will also be sharp on the film.

In 1925 a new kind of camera, the Leica miniature camera, was put on the market, it has remained popular ever since. The chief feature of the Leica is its small size It uses moving-picture film, thirty-five millimeters wide, in strips five feet long, thirty-six exposures can be made with one loading. Focusing is done with an optical range finder coupled with the lens By looking through a peephole, one may see two images of the subject. By moving the lens until the images are made to coincide, exact focus is secured. Today thirty-five-millimeter cameras are made by practically every camera manufacturer.

Good miniature cameras are distinguished by their precision workmanship. Clear, large pictures can be made by enlargers from the tiny negatives. The cameras can be used so inconspicuously that the subject is often unaware that he is being photographed; the result is an unposed "candid" picture. Because of this fact miniature cameras have sometimes been called candid cameras. Most photographers prefer, however, to apply the phrase "candid photography" to informal photographs made with any type of camera.

The lenses of good modern cameras are anastigmatic — that is, they form an image that is equally sharp at every point. The

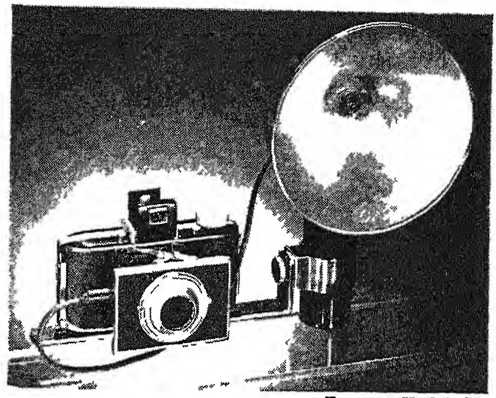
ordinary lens, as one can see by looking through a common reading glass, gives sharpness in the center part only. Optical glass varies in its power to bend, or refract, light-rays. By using different kinds of glass in combination in the same lens, it has been found possible to bring the marginal light-rays into the same focus as the central rays, thus securing flatness of field

Each lens has a definite "focal length." This is the distance at which the lens must be from the film in order to give a sharp image of a distant object The focal length of a common reading glass, for example, may be found by noting how far from a piece of white paper it must be held to form a brilliant and sharp image of the sun's disc. The greater the focal length, the bigger the image.

Most cameras are fitted with a lens of a focal length roughly equal to the diagonal of the negative. For example, the diagonal of a negative 4 x 5 inches is 6.403 inches; a 6-inch lens would generally be used with this negative size. For special purposes other focal lengths may be used: extremely short ones (wide angle) to give a large field; very long ones (telephoto) to give a big image of distant objects. In football games, sports photographers often use a "Big Bertha" camera, with a lens of 40-inch focal length; this gives an image five times larger than the average. The resulting pictures, although taken in the press box a hundred or so feet away, look as if they had been made right on the field

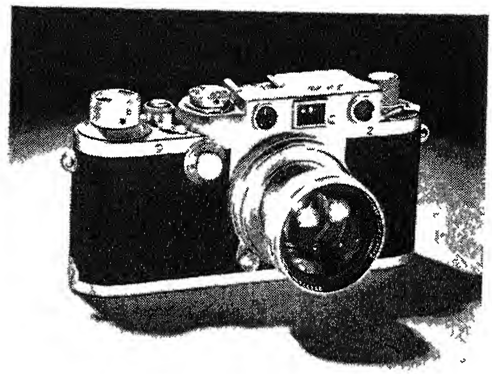
The power of a lens is measured by its diameter, which is indicated by a special formula. This is always in the form of a fraction, of which the numerator is always the letter *f*, standing for focal length. If a lens of 6-inch focal length is marked *f*/2 (which, of course, is equivalent to *f* divided by 2), it must be 3 inches in diameter. In this case we would call *f*/2 the *f* number of the lens. Lenses with the same *f* number have the same light-collecting power. The image formed by a 6-inch lens of 3 inches diameter is just as brilliant as that formed by a 2-inch lens of 1 inch diameter, since both are marked *f*/2.

An adjustable mask, called the "iris dia-



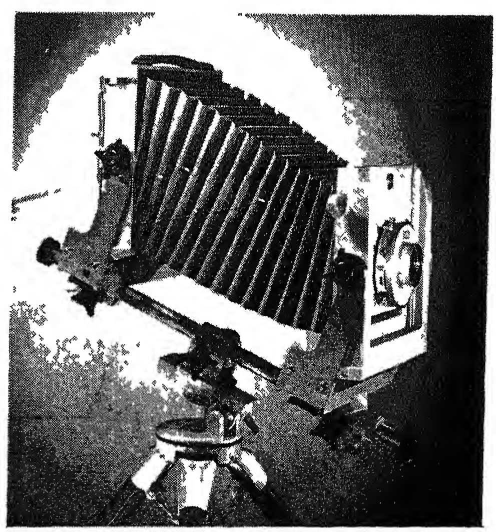
Eastman Kodak Co.

A simple camera provided with flash attachment.



E. Leitz, Inc.

This miniature camera uses moving-picture film.



Eastman Kodak Co.

A late-model view camera that is made of metal.

phragm," is fitted to the lens so that the diameter may be changed at will. The extent to which the diaphragm is "stopped down," or closed, is indicated by *f* numbers. Suppose, for example, that we adjust the diaphragm so as to decrease the diameter of a 6-inch lens from 3 to 2. In that case, we change the *f* number from *f*/2 to *f*/3. Diaphragms are generally stopped down following a definite sequence. The usual series is:

f/4 *f*/5.6 *f*/8 *f*/11 *f*/16 *f*/22 .

As one stops down from one of these numbers to the next, the amount of light reaching the film is decreased by one half, and correspondingly greater exposures must be given. If it is found that an exposure of 1 second is correct at *f*/11, we must give 2 seconds at *f*/16; we must give 4 seconds at *f*/22 and so on.

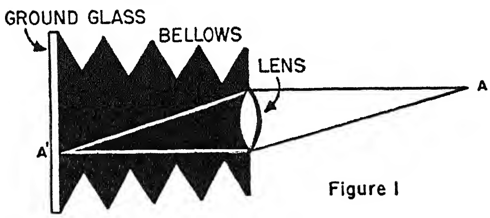


Figure 1

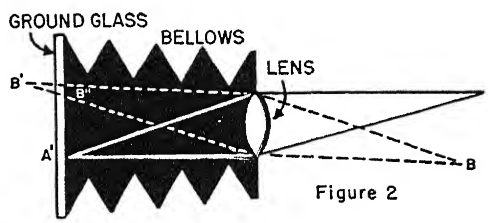


Figure 2

Only one plane can be in perfectly sharp focus at a given distance setting of the camera. Let us take any point in front of the camera — represented by A in Figure 1. A sharp image of that point will be created at A′ within the camera if the lens is at the proper distance from the ground glass. But, unless we are copying flat objects, we are interested in getting images of many other points both behind and in front of the one already in focus; for example, we might also want to get an image of point B in Figure 2. But point B is focused sharply at B′, at some distance behind the ground glass; on the ground glass at B″ we see not a point but a circular blur, a "circle of confusion," as it is called. Let us now increase the distance between the lens and the ground glass (Figure 3). Now A is represented on the ground glass not by a point, as was formerly the case, but by the circle of confusion that is indicated by A″.

Fortunately, our eyes are not perfect. We cannot distinguish the size of a circle smaller than $\frac{1}{100}$ of an inch; it appears to us as a point. If we can reduce B″ or A″ to a size smaller than $\frac{1}{100}$ of an inch, it will seem as sharp as A′ or B′. The diaphragm squeezes the bundle of rays so that the circle of confusion (A″) is decreased in size (Figure 4).

The lens is stopped down in order to secure great depth in the photograph. Camera manufacturers furnish tables that enable the user to calculate the depth of field at the various *f* numbers and distance settings. Box cameras are usually fitted with diaphragms that allow only two or three adjustments, and these are marked not with *f* numbers but simply 1, 2 and 3. Here the largest opening is 1 and the smallest is 3, corresponding approximately to *f*/11, *f*/16 and *f*/22.

Great advances have been made in lens manufacture in recent years; lenses of the power of *f*/1.5 or even greater have been introduced. Because of the great relative diameter of these lenses they have amazing light-collecting characteristics. This is coupled with a depth of field so limited that only short focal lengths have been found practical. Such lenses are used chiefly in moving-picture cameras and miniature still cameras. Another improvement has been the coating of lens surfaces with a thin film of fluoride in order to eliminate reflection within the various elements of a lens.

Exposure — admission of light to the film — is controlled by a shutter, usually a spring-operated device built into the lens mount. Exposures varying in length from 1 second to $\frac{1}{1000}$ of a second may be made automatically. Longer exposures, called "time exposures," are made by opening and

closing the shutter manually.

The sensitive salts that record the images — the grains of silver bromide or silver chloride — are fastened to sheets of celluloid by means of gelatin emulsion. There are two classes of film nowadays — "orthochromatic" and "panchromatic." These terms refer to the reaction of the sensitive emulsion to colors.

The primitive silver salt emulsions used in the early days of photography recorded blue as the lightest color and red as the darkest, indistinguishable from black. Landscapes in photographs taken in the 1860's show a blank white sky in which not a cloud is visible, because the blue of the sky was recorded as white; naturally the

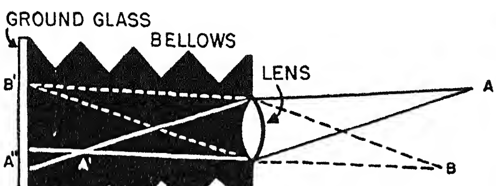


Figure 3

white sky and the white clouds merged. In 1874 Hermann Vogel discovered that the tendency of photographic emulsions to record blue as white could be controlled by dyeing the plate before exposure. This type of plate was called "orthochromatic" ("correctly colored," in Greek). Orthochromatic plates were sensitive to all colors except red. Since this was so, they could be developed by red light in an otherwise dark room.

In 1904 plates and films sensitive to red as well as the other colors were developed; they were called "panchromatic" (all-colored). Naturally these plates and films had to be processed in total darkness. Hurter and Driffield had demonstrated that it was not necessary to inspect the film while it was being developed; the time necessary for development could be calculated in advance. Gradually photographers began to follow this technique in developing their film and they turned more and more to the use of panchromatic film. Today these films are used almost exclusively.

Panchromatic films and plates offer various advantages. They make it possible to render colors in distinct shades of gray. Furthermore these tones may be altered at will by putting filters — colored pieces of glass — over the camera lens. A blue sky may be rendered as black; yellow stains on a document may be eliminated in a copy negative.

Panchromatic film offers a further advantage in photography by artificial light. Sunlight is a mixture of all colors; incandescent light is limited largely to the orange and red rays, the very colors to which orthochromatic film is least sensitive. By using panchromatic film, full use may be made of these rays.

The moving-picture industry has found

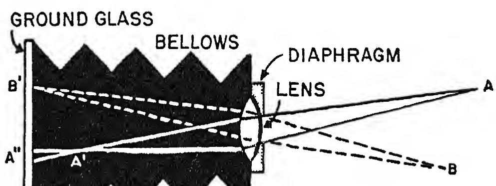


Figure 4

panchromatic film a godsend. Before the days of sound films, arc lights were used in the studios. These gave off all the colors of the spectrum and it was practical to use orthochromatic film. When sound came, the arc lamp had to be discarded because it sputtered and made disturbing noises. Incandescent lamps were substituted for them. As we have seen, these lamps are particularly strong in orange and red rays; hence the moving-picture industry adopted panchromatic films, which are sensitive to these rays.

In taking a picture, the most important factor is the amount of time that the film or plate is exposed to light. Gross underexposure will result in a negative so faint that it is useless; gross overexposure will produce a dense, almost opaque negative. Between these two extremes there is usually a wide choice of exposures that will result in printable negatives.

There are tables that give the average exposure required at different times of the day, at different seasons of the year and with different classes of subjects. These

EXPOSURE TABLE FOR BRIGHT SUN *

Kind of Film	Brilliant [1]	Bright [2]	Average [3]	Shaded [4]
PLUS-X	f/11 & 1/50	f/8 & 1/50	f/5.6 & 1/50	f/5.6 & 1/25
SUPER-XX	f/16 & 1/50	f/11 & 1/50	f/8 & 1/50	f/5.6 & 1/50

* For HAZY SUN, use the next larger lens opening. For CLOUDY-BRIGHT days, use 2 lens openings larger, and for CLOUDY-DULL days, use 3 lens openings larger.
[1] *Brilliant Subjects:* Beach, marine and snow scenes; distant landscapes and mountains without prominent dark objects in foreground.
[2] *Bright Subjects:* Near-by people in marine, beach or snow scenes; scenics with foreground objects.
[3] *Average Subjects:* Near-by people, gardens, houses and scenes not in shade. Use this classification if in doubt.
[4] *Shaded Subjects:* People, gardens and other subjects in the open shade (lighted by open sky — not under trees, porch roof, etc.).

tables are satisfactory for ordinary outside photography. Above is such a table, supplied by The Eastman Kodak Company for use with their roll films (1/50 and 1/25 in the table refer to shutter speed).

A more accurate way of determining speed is by the use of a photoelectric exposure meter. This ingenious instrument contains a photoelectric cell that converts light into electric current; the current is then measured by an ammeter. A general reading of the light reflected by a subject may be obtained by pointing the light-sensitive cell in its direction. From this reading the exposure may be figured on a built-in circular slide rule.

This is not the most efficient way to use the meter, however, because it does not take contrast into account. A white house on which the sun is shining brightly will have deep shadows under the porch and intense highlights on the walls. If insufficient exposure is given, the shadow details of the porch will not be recorded; if there is too much exposure, the texture of the walls will be lost. To balance the exposure in a case like this, the photographer takes two readings — one of the highlights and the other of the shadows — and he averages the two readings in calculating the exposure.

After film has been exposed, it is removed from the camera and developed. Most developers consist of mixtures of different chemicals. There is an organic chemical, like pyrogallol, which does the actual work of bringing out the latent image. There is also a chemical to make

The chemicals in the developer will act upon the film that was exposed to light in the camera.


In the developed negative, light and shade values are reversed. Thus light objects appear dark.


The negative is laid on printing paper, put in a frame and then exposed to a source of light.

the solution alkaline; a chemical that protects the developer from oxidation (combining with oxygen); a restrainer, to slow down the speed of the reaction. Through the action of the developer, the silver salts that have been exposed to light are transformed into grains of silver, which look somewhat like coke since they are not polished.

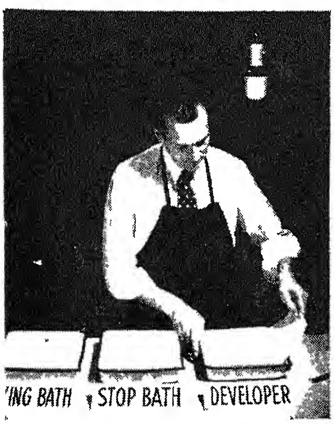
Sheet film is usually developed by inserting each film in a metal frame suspended in a tank. Roll film is generally wound on a reel of metal or bakelite; this is placed in a cylindrical tank. The developer is allowed to act on the film for a length of time determined, as we have seen, by the nature of the film and the composition and temperature of the developer. This information is supplied by the manufacturer of the film. The longer a film is left in the developer, the more contrast is built up. It is possible to make an exposure on a dull day, when the sun is hidden behind clouds, and by developing to make a negative that will appear brilliant.

After it is developed, the film is rinsed in a weak solution of acetic acid, which arrests the action of the developer. The film is then put into the fixing bath, a solution of sodium thiosulfate (commonly called "hypo," from its former name sodium hyposulfite). This chemical dissolves the silver salts that have not been exposed to light and that therefore were not reduced to metallic silver by the developer. Next the film is washed in running water for an hour; finally it is hung up to dry.

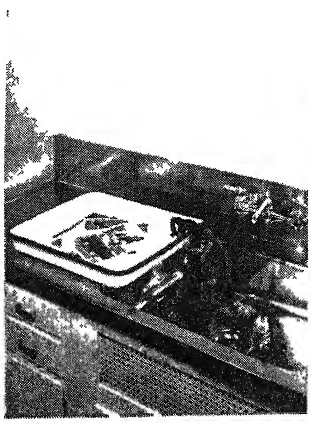
The negative is only a means to an end. Its value is determined by the kind of print that it will yield; this, in turn, depends on the particular kind of printing paper that is used. Most prints today are made on paper coated with gelatin with which light-sensitive silver salts have been mixed. This emulsion is similar to that used for negatives, except that it is less sensitive.

There are two methods of printing: by contact and by projection. Contact prints are the same size as the negative. The paper is pressed tightly against the negative in a glass frame. After being exposed to the light of an electric bulb for a few seconds, the print is developed, rinsed, fixed and washed. These operations are done in trays by yellow light.

Prints larger than the negative are made by projection. This involves the use of an enlarger, a piece of optical equipment similar to a lantern-slide projector. Strong light is thrown on the negative; a lens then projects the negative image to any desired size on an easel, on which sensitized paper is placed. The processing is identical to that employed in contact printing. Since the emulsion of enlarging paper is more sensitive than that of ordinary contact paper, it takes less time to make enlargements than it does to make contact prints.



The chemicals in the developer act upon the coating of the paper. Gradually the picture appears.



After being fixed, photographic prints must be washed thoroughly in running water.

This is the final result, after the print made from the negative has been washed and then dried.

In the Land polaroid camera, invented by Edwin H. Land, developing and printing take place within the camera (Figure 5). A pair of small rollers are fitted into the camera; one contains the film, the other a roll of sensitized paper. After a picture is snapped, a turn of a knob advances the film and paper through pressure rolls. As a small vial (the pod) passes between the pressure rolls it is broken. The contents of the vial (developer and hypo) develop and fix the negative and make the positive print. The paper is then to n off against a sharp edge; the negative is lost in the process.

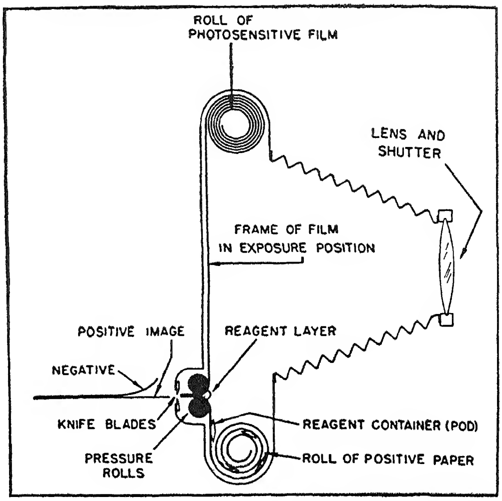
There are times when natural lighting is not the best for the photographer's purpose. The subject may be too dimly lighted to permit good photography; or natural light may not produce a desired effect. The development of powerful electric lights — spotlights and floodlights — and of flashlights have made it possible to obtain the sort of photograph that one wants at the very time when one wants to take it.

The use of floodlights and spotlights

Most portrait photographers use floodlights and spotlights. A floodlight is simply an electric bulb placed in a reflector, which is shaped like a bowl or an open-ended box. A spotlight is a bulb used with a lens; it produces a beam of light. The floodlight gives diffuse, general illumination; the spotlight produces crisp, strongly defined shadows. Both are commonly used: one or more floodlights to give general illumination and to soften the shadows; the spotlight to give the main lighting emphasis and to pick out details. The use of artificial lighting has become an important part of photography; a photographer is often judged nowadays on the basis of his ability to light his subject effectively.

Photoflood bulbs are a boon to the amateur

A few years ago "photoflood" bulbs were introduced. These are lamps that are designed for low voltage but that burn brilliantly for a few hours on the usual 110-volt house current. With these bulbs the amateur has brilliant illumination at his disposal, and he can easily make fine snapshots at home even with the most inexpen sive camera.



Polaroid Corporation

Figure 5. Diagram of the Land polaroid camera, which turns out a finished photograph a minute or so after the shutter is snapped. The camera contains not only film but also printing paper, developer and hypo. Details of the operation of the camera are given on the preceding page.

Flashlights are particularly valuable in taking photographs when lighting conditions are bad. Magnesium in powder form (also in ribbon form) was used for this purpose for many years. Flash powder, as it was called, burned with such great brilliance that fully exposed negatives could be made by its light in the fraction of a second. But it was a dangerous substance with which to work. The material was so combustible that it sometimes exploded prematurely; its ignition close to the photographer was always risky.

In 1928 an effective substitute for flash powder — the flash bulb — was developed in Germany. It resembled an ordinary electric lamp, but it was filled with magnesium foil that could be ignited at will merely by passing a weak electric current through it. This development has revolutionized flashlight photography.

An amateur can make a fine indoor exposure with any camera by using the "open flash" technique. The camera is fastened

to a support and fresh film is set in place within it. The flash bulb is screwed into an ordinary lighting fixture or into a battery case held in the hand. When the picture is to be made, the camera shutter is opened. The flash bulb is set off and then the shutter is closed. To secure good results both the camera and the subject must remain perfectly still during the time that the shutter is open. A more effective method for taking flashlight pictures has been developed. In this, the electrical contact is made at the precise instant that the shutter is operated. When this method is used, the camera can be held in the hand; subjects in rapid motion can be "stopped."

News photographers, who must "get that picture," now make almost all their exposures by flashlight. The great drawback is that it is difficult to visualize the final result; all too often photographs taken in this way have a harsh, unreal character. To soften the lighting effects, two or more flash bulbs are often used at the same time; these are placed at varying distances from the camera and are connected with a master synchronizer. Synchronizers have also been built into the mechanism of the shutter itself.

Making exposures by electronic means

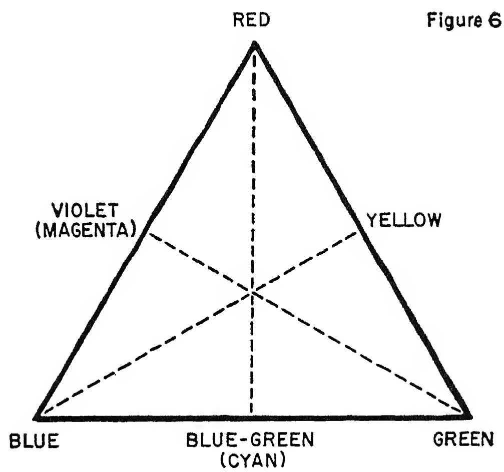
The shortest exposure that can made with a mechanical shutter is $\frac{1}{1000}$ of a second; but exposures of millionths of a second can be made by electronic means. Electrical energy is built up in a condenser to an extremely high voltage and is then released in a gas-filled tube. Light of intense brilliance is created for an infinitesimal period; it is commonly called a "strobe light," from the stroboscopic effect given when the electronic flash is repeated. (A stroboscope is an instrument used to study the different phases of motion by means of a source of light that is periodically interrupted.) The shutter of the camera is left open until a picture (or a series of pictures) is taken by the electronic flash; this is so brilliant that ordinary room lighting has no effect upon the film during the brief interval that the shutter is open.

The electronic flash can be repeated at will. The intervals between the flashes can be regulated, and multiple exposures of moving objects can be made; for example, the arm of a tennis player can be shown in a number of different positions in the same picture (see page 3984). This is called "stroboscopic photography."

In the early days of photography Daguerre expressed the hope that some day men might be able to record the color as well as the form of the natural world by photographic means. Today color photography has become a widely practiced and effective art. It is based on indirect techniques; no one as yet has found a substance that will immediately assume the color of all the light-rays that fall upon it.

To understand the use of color processes in photography, we must recall that the white light of sunlight is made up of hundreds of distinct colors, one merging into the other. The principal colors are the familiar rainbow hues of violet, indigo, blue, green, yellow, orange and red.

Figure 6



Clerk Maxwell's color triangle. The colors that are connected by dotted lines are complementaries.

In 1861 the eminent Scotch physicist James Clerk Maxwell showed that these colors could be reduced to three primary colors which, when added in equal proportions, form white.

RED + BLUE + GREEN = WHITE

Acme

Like the postman, the news cameraman is out in all kinds of weather. Here two photographers are recording a two-foot snowfall in New York City.

He showed also that these primary colors, mixed in suitable proportions, can reproduce any color. To illustrate his theory, he developed the color triangle shown in Figure 6.

The colors midway between the corners of the triangle are formed by mixtures of the adjacent primary colors. Thus:

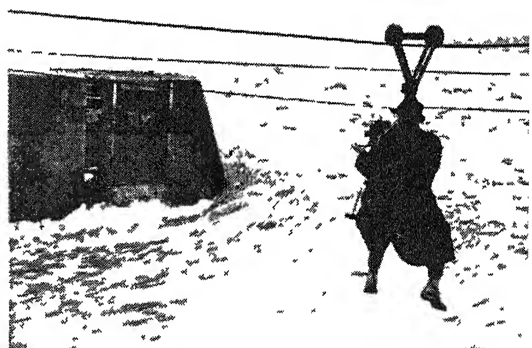
RED + BLUE = VIOLET

The colors opposite one another, connected in the diagram by dotted lines, are called complementaries. Violet is the complement of green; blue-green is the complement of red. When colors that are complementary to each other are mixed, white light results. The reason will be perfectly clear if we examine the three following equations:

(1) RED + BLUE + GREEN = WHITE (The three primary colors form white when combined.)
(2) RED + BLUE = VIOLET (Violet is a mixture of red and blue.)
(3) VIOLET + GREEN = WHITE (Substitute Violet for Red + Blue in Equation 1.)

If a photographic record can be made of the amount of each of these primary colors in any subject, it is possible to recreate the original colors from that record. James Clerk Maxwell was the first to do so He made three black-and-white negatives of a subject, one through a red filter, another through a green filter and still another through a blue filter. The red filter transmitted the red rays but held back the green and blue rays; the green filter transmitted only the green rays; the blue filter, only the blue rays.

From each negative he made a positive lantern slide, which he projected on a screen in a darkened room. The three projectors were arranged so that the images fell on exactly the same place on the screen.



Wide World

A news photographer risks his life to get a close-up shot of flood waters sweeping over a dam Such risks are considered to be all in the day's work.

He now put the red filter in front of the projector containing the slide made from the red filter negative; he put the green filter in front of the slide made from the green filter negative and the blue filter in front of the third slide. The red, blue and green rays blended on the screen and a full-color photograph appeared on the screen. Color photographs of this sort are called "additive," because the primary colors are added to one another.

In another additive process, a single negative is taken through many filters. Starch grains are divided into three equal lots; one of these is dyed red, the second green and the third blue. The grains are then

thoroughly mixed together, spread on the back of a glass photographic plate and fastened there by varnish. Each grain acts as a tiny filter; where it is located, a minute record of that color is secured. After exposure the negative is converted to a positive; the starch grains remain in place. The plate then becomes a transparency, in which the colors are supplied by the starch grains. This technique was very popular early in the twentieth century; it was called the Autochrome. It is now obsolete.

The additive process is still used in preparing plates for color printing. However, the most recent processes in photography are all based on the "subtractive" theory of color mixing. The color of an object is due to the fact that certain wave-lengths of light are absorbed (or subtracted) while others are reflected. A blue-green object subtracts red and reflects blue and green rays. In red light this blue-green object appears black, because, since neither blue nor green are present in red light, there is nothing to be reflected. The colors subtracted by the primary colors are their complementaries:

WHITE − RED = BLUE-GREEN (BLUE + GREEN)

WHITE − BLUE = YELLOW (RED + GREEN)

WHITE − GREEN = VIOLET (RED + BLUE)

To make a photograph by the subtractive method three negatives are taken, exactly as in the additive process, through red, green and blue filters.

(1) In Negative A, taken with the red filter, red will be filtered through and the complementary color, blue-green, will be subtracted.

(2) In Negative B, taken with the green filter, the green will be filtered through and the complementary color, violet or magenta, will be subtracted.

(3) In Negative C, taken with the blue filter, the blue will be filtered through; yellow, the complementary, will be subtracted.

Lantern slides are now made of the three negatives, and each is dyed in the color complementary to that of the filter through which the negative was taken. This means that the colors subtracted from the negatives have now been restored; hence, when the three slides are placed in contact with one another on a projector, they reproduce the original colors of nature.

It is not necessary to make lantern slides in order to prepare a color photograph by the subtractive process. Prints can be made from the negative on paper, and then dyed the appropriate colors of blue-green, yellow and violet. By delicate manipulation, the emulsion can be removed from the paper and placed on a fresh support. The three emulsions are then placed on top of each other. This is the principle underlying the "wash-off relief" and "carbro" processes. In the "dye-transfer" process the negatives are first printed on a special gelatin material which records the highlights and shadows in relief. These matrices are then dyed red, blue and yellow. When the matrices are pressed in turn against paper, the dye is transferred in exact proportion to the tonal scale of the subject.

The single-exposure method of color photography

In certain processes — Kodachrome, Kodacolor, Agfacolor and Anscocolor, among others — a single exposure is taken on a specially prepared film. In the Kodachrome process, one piece of cellulose acetate is coated with three emulsions, sensitive respectively to blue, green and red rays. Between the blue sensitive and green sensitive emulsions there is a layer of yellow dye that acts as a filter to subtract the blue rays and thus to prevent them from reaching the other emulsions. The three emulsions are developed to negatives and, by a special technique, reversed to positives. In the process the layers are dyed respectively yellow, magenta and cyan. The result is a color transparency. Color prints on paper can be made from transparencies of this kind.

The uses of photography in the world of

today are legion. Amateur photography is flourishing as never before; the use of the camera to make a complete pictorial record of one's own doings and those of one's family and friends is all but universal.

Modern portrait photographers excel in catching the characteristic moods of their subjects and in creating, not stilted poses, but real portraits. Commercial photographers play an important part in the world of industry and in the field of advertising, which brings the products of industry to the attention of the public. News photographers have also come very much to the fore. The photographs appearing in newspapers and magazines present a marvelously accurate pictorial record of our age — its pageantry, its disasters, its personalities and the innumerable passing incidents that are the very stuff of which life is made.

Photography has been utilized to make reproductions of documents; these copies are exact images of the original, produced on sensitized paper. The photographic process is also used in microfilming — that is, the reproduction of documents, such as checks, maps and the pages of books or newspapers, on narrow ribbons of film; the film is developed and then enlarged by special reading devices. (See Index, under Microfilming.)

The moving-picture industry, of course, is based on photography, since motion pictures are simply photographic stills, run together so rapidly in the projector as to give the illusion of continuity.

Henry M. Lester

Photography aids science: taking high-speed photographs of a fly that is held by wax on a pin.

Photography has been of immense value in furthering the progress of science. The beating of the human heart, the tremors caused by an earthquake, the readings of the barograph, which registers differences in atmospheric pressure — all have been recorded on photographic film. The analysis of light by the spectroscope is generally entrusted to photographic films or plates. Through photography, nuclear physicists can study the break-up of atoms in a cloud chamber. Tiny objects, far too small to be seen by the naked eye, have been permanently recorded on film by photomicrographs — photographs taken by cameras fitted to microscopes. Radiography — photography by X rays — has become an indispensable aid in the diagnosis of human ills. The astronomer finds photography absolutely essential in his work; so much so, indeed, that photography has replaced visual observation of the heavens to a large extent.

Photography makes it possible to obtain rapidly an accurate picture of the earth's external features. It has proved to be of the utmost value in surveying; it has also revolutionized the technique of military reconnaissance.

It is difficult to predict future trends in photography. Undoubtedly great technical advances will be made in color techniques; we may expect that the present cumbersome processes will be supplanted by some form of direct recording of colored light. Negative material of greater light-sensitivity will probably become available. Developing and fixing agents in the gaseous state may replace the present materials; "dry plate photography" will then no longer be a misnomer.

Perhaps the greatest advances will be made by applying to photography the principles learned in the development of television. The day may not be far distant when the camera will be an electronic instrument, transmitting impulses to a laboratory, where the image will be instantaneously fixed in any desired size and tonal contrast.

THE WORLD OF SENSATION

Man's five senses — vision, hearing, touch, taste and smell too narrow a list

WHAT MAKES FOR CONSCIOUSNESS

MAN is the possessor of two worlds. One is the external world of nature around him, consisting of matter, energy, and the abounding but ever mysterious forms of life. The other is the world of consciousness within himself. The countless forms of matter, such as iron, oxygen, water, etc , we are acquainted with, as well as the manifestations of energy in sound, light, electricity and heat. Some of the differences between living and nonliving matter we also know; but the profound secret of life itself lies at present beyond our grasp. Consciousness is also impossible to explain in terms of our knowledge acquired from the study of the material world. Hence its nature has long been the subject of controversy. Nor do the definitions of philosophers assist us greatly in its understanding. "Consciousness", says Locke, "is the perception of what passes in a man's own mind". Again, "Consciousness", says Porter, "is briefly defined as the power by which the soul knows its own acts and states". There is, too, a moral and religious consciousness, which deals with matters beyond the world of sensation; but with those phases of this great fundamental subject we are not at present concerned. By our own consciousness we are aware of being alive, of experiencing sensations, of possessing knowledge, memory and emotions, of exercising reason and will-power.

Consciousness has its seat in the brain where it is shut off from the exterior world and from the rest of the body by the strong, protecting walls of the skull. In order to afford means of obtaining information from the organism itself, and from our environment of the natural world, the skull is perforated by openings through which extends a marvelous system of communicating fibers or nerves.

The whole nervous system is divided primarily into two great parts: first, the central nervous system, consisting of the spinal cord safely enclosed within the backbone, and the brain which comprises chiefly the cerebrum in the upper part of the skull and the cerebellum beneath it; and, second, the peripheral nervous system, which consists of 43 pairs of nerves, 12 pairs from the cerebrum, and 31 from the cord, radiating to all parts of the body. These fibers are like white threads, of microscopic diameter, but of various lengths up to about three feet, according to their position and function. The nerve fibers are capable of conducting impulses or waves of electrochemical change at a velocity in man of about 400 feet per second A single impulse in a nerve raises its temperature about one ten-millionth of a degree

Important as are the functions of each part of the central nervous system, those performed by the cerebrum greatly surpass them all, inasmuch as it is the organ of sensation and the particular abode of consciousness. In appearance it is extremely wrinkled, something like a walnut, and divided also into two hemispheres. Its outer part, which is called the cerebral cortex, consists of brain cells of gray matter. The purpose of the wrinkles or folds is to provide as much space as possible for the all-important gray matter.

The cerebral cortex as highly organized as a group of executive offices

Different areas of the cortex receive nervous impulses from the various sense organs or receptors, and in turn send out at will impulses which control definite parts of the body. In this respect it is as highly and efficiently organized as, for example, any group of executive offices of a great railway organization can possibly be. These various areas are also elaborately interconnected by vast numbers of association nerve fibers, the white matter of the brain, by which they are maintained in constant communication with each other.

The nerve fibers of the peripheral nervous system are divided into two great classes; first, the afferent nerves, which carry messages from the body and the external world to the brain: and, second, the efferent nerves, which carry impulses from the brain to the muscles and glands by which consciousness is enabled to put into effect its desires and dictates, by moving the muscles and promoting secretion by the glands.

By means of the afferent nerves, which are five times as numerous as the efferent, consciousness is supplied with all its enormous variety of information, while through the efferent nerves consciousness gives practical effect to that information.

At their peripheral ends the afferent nerves are attached to end-organs called receptors. These are of great variety and highly specialized, so that each kind can transform, probably through some peculiarity of substance or form, a particular type of stimulus into nervous impulses which, when conducted to the proper cortical areas, give rise to specific sensations.

All nervous impulses, whether afferent or efferent, are exactly alike; the only reason why some excite sensations of light and others sound, for example, is because they terminate in different cortical areas, which by some remarkable but unknown power are inherently capable of producing those sensations. If it were possible to interchange the nerves of vision and hearing, we would be able, as someone has said, to hear the lightning and see the thunder.

Efferent impulses likewise differ in their effects only because they terminate in different muscles and glands, which are called the effector organs of the body. If the nerves controlling the feet and hands were to be interchanged, we should move the hands when we tried to walk, and gesticulate with our feet during a speech.

The receptors sometimes, as in the eye, ear, tongue and nose, are concentrated in small areas; in other cases, as in touch, temperature and pain, they are widely distributed over the whole surface of the body. All types, except those of pain, are so highly specialized that only one kind of stimulus — the adequate — is usually capable of generating nervous impulses in them. For the eye the adequate stimulus is a certain range of ether waves which we call physical light. For the ear it is the range of waves in the air called music or sound. Sometimes additional inadequate stimuli are effective to some extent, as, for example, a blow on the eye causes the recipient to "see stars", and an electric current occasions a flash of light.

How the reflex arcs produce automatic action without brain fag

Since there are over twenty recognized senses, the field of consciousness is continually being flooded with sensations. If these all required attention, the mind would soon become excessively wearied and cease to function. To avoid this disastrous possibility, the nervous system has been arranged, in part, on a plan of what are called "reflex arcs". This consists of groups of afferent and efferent nerves designed to produce automatic action without requiring time for consciousness to deliberate about it. If, for example, one touches a finger to a hot stove, the hand is drawn away almost instantly; that is, as quickly as an afferent impulse can travel to the brain and an efferent impulse travel back to the muscles of the arm. This series of actions requires time, though it is, of course, very short, so that the finger receives a burn. If, however, one had to take time to think about what he should do, a very severe burn would result before the hand could be pulled away.

An enormous number of our actions and habits are of the reflex type, by which consciousness is relieved of an intolerably heavy burden of responsibility. Nervous impulses arising from the motion of liquids in three semicircular canals in each of the ears automatically evoke reflex actions which control the muscles required to preserve the body in an erect position. The rhythmical motion of the limbs in walking is maintained by reflex action. When the regular action of the nerves is interfered with by alcohol, the reflexes do not operate smoothly and the irregular walk of the intoxicated person results. Learning to play a musical instrument is a process of establishing new reflex associations between the eyes, and ears and the hands. Until this is accomplished practising is slow and painful, since the eye has to see the notes, the brain to think about their significance and finally actuate the proper muscles to strike the keys.

The classification of the receptors of the body and their three fields

The receptors of the body may be classified in several ways. The system devised by the celebrated British physiologist, Sir Charles Sherrington, seems to be the simplest and most natural of all. In this classification the receptors are grouped according to their position in the organism. An additional advantage is thus gained, since the location of the receptors is also significant of their function.

The receptive fields are three in number: first, the exteroceptive field, which includes the receptors lying on the external surface of the body, such as those of touch, cold, warmth, pain, vision, and hearing; second, the interoceptive field, which comprises the receptors of taste, smell, hunger, appetite, thirst, etc., lying on the inner surface of the body, the mouth, stomach and alimentary canal; the proprioceptive field (Latin *proprius* = belonging to one's self), which includes the receptors in the joints, muscles, and tendons, and all others situated within the tissues of the organism, from which originate the muscle sense, the sense of position and the vaguely located sensations of fullness, emptiness, nausea. dizziness, rest, fatigue and the like. Broadly speaking, it is by means of the proprioceptors and interoceptors that we acquire a knowledge of ourselves or have self-consciousness; by means of the exteroceptors we have world-consciousness.

In regard to the relation between the parts of the central nervous system, and the three receptive fields, it may be said that the cerebellum is the central organ of the proprioceptive senses, while the cerebrum is that of the other receptive fields. The cerebrum, however, as the seat of the mind and consciousness dominates the whole.

The receptors may also be classified in accordance with the characters of their adequate stimuli. Thus the touch receptors are stimulated by contact with solids, the taste receptors by liquids, and those for smell by gases and vapors. From still another point of view the visual and auditory receptors, and to some extent those of temperature (warmth), respond to wave stimulation and consequently may be termed radio-receptors. The receptors of taste and smell are stimulated by chemical action and are therefore termed chemoreceptors. Another group of receptors, those of the common chemical sense, may also be included in this class. They are situated close to the apertures of the body, such as the mouth and eyes, and respond to irritating chemicals such as ammonia, the odor of onions, etc. A third group, consisting of the receptors for touch and temperature, are termed the mechanoreceptors, which are stimulated by contact with solids and liquids.

How many senses may man eventually be recognized to possess?

Man is commonly held to possess but five senses, vision, hearing, touch, taste and smell. Sometimes the question is raised of the possibility of the acquirement of a sixth sense. It is now evident that our senses number far more than the traditional five, for as many as twenty distinct sensory responses have been recognized by psychologists, and probably more will be identified as scientific investigation progresses farther.

Sensations exist only in our consciousness within the cerebral cortex By a most remarkable power, however, they are not felt to be there, but are usually projected to the periphery of the body where the stimulation of the receptors occurs, and even to the object where the stimulus originates The sensation of hunger exists only in the brain, but it is projected to the stomach, where the stimulation takes place. Likewise the sensation of thirst appears to be located in the throat. In other senses this power of projicience, or projecting the sensation, is differently developed. When a cold object like ice or a hot piece of metal touches the temperature receptors, we attribute the coldness to the ice and the warmth to the metal. In the sense of touch projicience is even more highly developed. For if we hold in our fingers a pencil or a rod and touch the free end to any object, the sensation seems to be transferred to the point of contact even if many feet distant. In the sense of taste it appears to be the substance in contact with the tongue that possesses the bitterness or sweetness, and flowers are regarded as odorous, whereas these qualities of taste and smell are not attributes of the objects but exist only as sensations in the recesses of the brain. In the sense of hearing the musical sensation is projected to the instrument from which the atmospheric waves emanate, whatever the distance that separates it from the ear.

It is in the sense of vision that this power is developed to the highest possible degree. In consequence this sense becomes by far the most important of all. Color is attributed to the sky, and light to the sun and stars which are practically at infinite distances from us. Yet in every case the light and color are sensations existing wholly within the brain. By this extraordinary attribute of consciousness the world without us, from objects in contact with the body to the remotest star, creates a corresponding world of sensation within.

All sensations have certain attributes in common. They possess quality, intensity, local sign and extension. The quality of a sensation is the characteristic that differentiates or distinguishes one sensation from another, such as hunger from thirst, cold from warmth, vision from hearing. It is obvious, too, that we can distinguish between the low intensity of a dim light and the high intensity of a bright light, between heavy and light pressures, between feeble and loud sounds. When any point on the surface of the body is touched, consciousness is at once aware of the exact locality in which stimulation occurs. This power of localization is termed local sign or signature. In some senses, such as touch, temperature, pain, etc., local sign is usually highly developed. But in the more vague sensations, such as visceral pain, hunger, fatigue, and the like, local sign may almost vanish. Finally we are aware, not only of the locality stimulated, but also the extent of surface involved.

The attribute of variable sensitivity of the receptors which is termed "adaptation"

The thresholds of response of receptors, or the weakest perceptible stimulation, are not absolutely fixed, but are determined by the sensitivity of the receptors, which varies with their state of adaptation. At one time weak stimulation suffices to evoke a sensation; at another time under different conditions a more intense stimulation may be required. This attribute of variable sensitivity has been termed adaptation. Without this power the receptor organs would probably react to a very limited range of intensities of stimulation and be quite unresponsive to intensities above or below that range. By means of adaptation the eye is able to function at one time in very dim light, at another in the brightest sunshine. The visual receptors may have induced in them a state of darkness adaptation, of dim light adaptation, or of bright light adaptation; they may also become adapted for red light or for light of any other color. Everyone has noticed that after the eyes have been exposed to bright sunshine, especially when the ground is covered with fresh snow, the subdued light of the interior of a building makes scarcely any impression upon the retina at first, though after a few minutes the same light is found to be ample for working or reading. When awakening at night, if the

dark-adapted eyes are suddenly flooded with bright electric light they are so painfully dazzled for a time as to be incapable of vision.

The complete range of sensitivity of any class of receptors has been termed the "amplitude of adaptation". While in most senses it is not very great, in the eye it is exceptionally large The preëminence of vision among the senses is due in large measure to the extraordinary magnitude of this power.

The velocity with which a sense organ adapts itself to changing conditions of stimulation is extremely variable. In darkness the sensitivity of the eye increases perceptibly for several hours; while the reverse process of light adaptation is completed within a few minutes.

In the sense of touch the characteristics of adaptation are also very pronounced. The pressure of glasses on the nose, of artificial teeth upon the gums, and of unaccustomed clothing upon the skin may be extremely irritating when first applied, but through the power of adaptation they gradually become unnoticeable. The amplitude of adaptation in this sense, though not so great as in vision, ranges from the exquisite delicacy of tactile sensibility of the finger-tips, which is displayed in the finest performances in the arts and industries, to the coarse tactual responses arising from the roughest occupations of life.

Adaptation of the temperature receptors is much more generally recognized. The body speedily becomes accustomed or adapted to the differences of temperature between winter and summer, and to the great climatic extremes of polar and tropical regions. These facts sufficiently indicate the amplitude of thermal adaptation, while its velocity is shown by the ease and quickness with which the organism adjusts itself to the change from indoor to outdoor temperatures in winter.

The delicacy of adaptation of the sense of smell enables the odorous substance, mercaptan, when diluted to one part in fifty billion parts of air, to be detected. The velocity of adaptation is shown by the rapidity with which the oppressive odor of a close room ceases to be noticed.

Perhaps in no sense organ is the power of adaptation more obvious than in the auditory receptors. Dwellers in cities near railway lines soon become so accustomed to the roar of traffic that it ceases to annoy in daytime or to disturb sleep at night. In contrast with this the unbroken quietness of a night in the country may at first be more disconcerting than the noises of the city, until the process of adaptation to the new condition is complete.

In the muscle sense, in the senses controlling posture, in pain and hunger, etc., it will be found that the receptors are susceptible of acquiring varying states of sensitivity so as to provide consciousness with the widest possible range of information.

In addition to the information which our senses afford by acquainting us with the bare facts that, for example, objects are hot or cold, rough or smooth, plane or curved, wet or dry, still or moving, tasteless and odorless or possessing taste and odor, there is associated with them a wonderful power of exciting pleasurable or displeasurable feelings as well. This is called the "affective" or "feeling tone". Thus musical sounds are more than rhythmical, physical vibrations: they kindle our emotions or soothe our feelings. Drawing and color, in the form of pictures, are elevated by the affective tone associated with vision into perceptions of the highest forms of beauty. Pleasurable feelings of a wide diversity of type are found with all the sensations we experience. Indeed, the whole of our enjoyment of physical life arises from the pleasurable feeling tone associated with sensations.

There is obviously a darker side to these experiences. For sensations are also capable of conveying or exciting feelings of a displeasurable nature. So discordant sounds are repellent; some combinations of colors are repugnant to our æsthetic perceptions; tastes and odors may excite feelings of disgust.

The affective tone has a most practical application. For by its use we are able to avoid those objects and conditions which are harmful to the organism; or we may be able to judge whether or not the body is

in a normal healthy condition. Wholesome foods properly excite feelings of pleasure associated with their tastes and odors; but when we become ill the feeling tone elicited by the same sensations may be highly displeasurable and often repellent in the extreme.

The erect position of man and how it is maintained

Having considered the mechanism of the nervous system and the general characteristics of receptors and sensations, we may now review in some detail some of the more important senses. Since the general purpose of the splendid diversification of sensations is to awaken and maintain world-consciousness and self-consciousness, and to preserve life, we may study them in the order in which they contribute to these ends.

The fundamental force in the physical world is gravitation, without which, indeed, no ordered system of the universe would be possible. The erect posture of man, peculiar to himself, which determines his outlook upon the world and his orientation within it, is conditioned directly by this force. Gravitation thus assists in unifying man with the material world as far as his body and his sensory organization are concerned. It follows, of course, that our habits of eating and drinking, the shapes of our houses, furniture, utensils, tools, and all occupational contrivances are determined by the fundamental requirements of the erect posture. Perhaps it will not be going too far to say that in man the arrangement and coördination of all sense organs are primarily conditioned by the elementary fact of posture. From this point of view we may at the outset consider how this position is maintained.

First of all, the forms and articulations of the bones of the skeleton and the arrangement of the muscles controlling them, render necessary the erect position. But when one stands upright the body is in unstable equilibrium and is constantly tending to fall in one direction or another. To prevent this occurrence the center of gravity of the body must be kept directly above the feet by the operation of groups of muscles acting in opposition to each other. But before the muscles can be adjusted some sensory stimulation must occur.

The origin of stimulation is in the labyrinths of the inner ears, which consist of several very small organs. In one of them, the utricle, are several small grains of calcareous matter, called otoliths, which, when the head is moved, touch different nerve-endings or receptors and thereby cause afferent impulses to be sent to the central nervous system. Another part of the labyrinth consists of three semicircular canals arranged in three planes at right angles to each other, one nearly horizontal, another in a vertical plane in the direction from front to back, and the third in a vertical plane in the direction from side to side of the head. The motion of the head disturbs the thick fluid in the canals, which stimulates the hairlike nerve endings projecting into the liquid. Both sets of afferent impulses by reflex action evoke efferent impulses which descend from the central nervous system to the groups of muscles controlling posture, and thus maintain the equilibrium of the body without the intervention of consciousness. The utricle particularly controls changes in position, and the canals changes in motion.

The labyrinthine sensations usually perform their functions below the level of consciousness, though in rapid changes of motion sensations of dizziness may become extremely intense as well as disagreeable. The labyrinth is by far the chief of the proprioceptive sense organs, standing in relation to them much as vision does in the exteroceptive field. The general import of its functions in regard to postural reflexes is contained in Sherrington's summary: "It keeps the world right side up for the organism by keeping the organism right side up to its external world".

Other receptive systems also contribute to the maintenance of posture, such as the receptors of the muscle sense in the muscles and tendons, the pressure of the feet upon the ground, the visual and the auditory receptors. All of them are capable of initiating reflex actions in the muscles which, whether the body is standing or in motion, preserve its equilibrium.

The muscle sense through whose instrumentality the organism performs its tasks

While the muscle sensations do not usually awaken a conscious response, their functions are of the utmost importance, since through their instrumentality the organism performs its tasks. By their action we are constantly aware of the positions and motions of the limbs. If, for example, we move our hands behind our backs, or in front if the eyes are closed, the corresponding finger-tips may be quickly and accurately brought together. The most delicate operations in the fine arts and industries are by the muscle sense executed with admirable precision. The same sense enables the musician to strike the keys, or bow the strings, of musical instruments with such finely graduated intensity that the music is given any expression desired. Music practice is, to a large extent, the development and control of the muscle sense.

By the muscle sense we adjust the force of the arm so as to drive a tack, a nail or a spike. So also the force with which a tennis or a golf ball is struck is nicely adjusted by the same sense to the direction and distance desired. When the body is disturbed in the slightest degree, the receptors in some parts of the muscle system become stimulated by changes in pressure, and the labyrinthine receptors are aided in accomplishing the necessary readjustments to maintain equilibrium.

The sense of vision and how the eyes "accommodate" themselves to distance

The two eyes, which are the peripheral organs of the sense of vision, are set in strong, protecting cavities in the head in such a position that the axis of vision is horizontal, and thus at right angles to the vertical postural axis of the body. Each eye is globular in form, and in construction like a camera. Probably it would be more appropriate to say that a photographic camera is modeled after the eye. The rays of light reflected from objects pass through the transparent cornea and then enter the pupilary opening in the center of the colored iris diaphragm, which, by reflex action, automatically adjusts its size to the intensity of the entering light. The rays, converged or refracted toward each other, then pass through the transparent crystalline lens and finally are brought to a focus on the sensitive screen, called the retina, at the back or fundus of the eye. In a camera the images of near and distant objects are focused on the sensitive plate or film by moving either the lens or film backwards or forwards. But in the eye both lens and retina are fixed in position, so that focusing can only be accomplished by changing the curvature of the elastic lens. This is also done automatically by reflex action, with such rapidity that we are conscious of the operation only when we look attentively and quickly from near to distant objects. This is called the "accommodation", and it proceeds simultaneously in both eyes. In early life the shortest distance at which distinct vision occurs is about four inches; but it gradually increases to about ten inches, at which it remains until the age of forty to fifty years is reached. The muscles of accommodation then relax and the distance of distinct vision increases, so that glasses become necessary to assist the eyes and reduce strain.

In some eyes the lens is too much curved and causes short-sightedness; in others the lens is too flat and long-sightedness occurs. In these cases the images cannot be focused on the retina, and vision accordingly is indistinct. Should the lens or cornea be slightly cylindrical in shape instead of truly spherical, points on the object are drawn out into lines on the image, which becomes blurred and distorted. This is called "astigmatism". Happily these defects can all be remedied by suitably curved glasses.

The question naturally arises why two eyes are provided instead of one. Space has three dimensions, and the perception of depth and the judgment of distance are extremely important ocular functions. While with a single eye both functions are possible, yet they are far more readily and accurately accomplished with two. By means of intercommunicating nerves, the two eyes act most perfectly in combination with each other, yet each can act independently

to such an extent that all their powers can be exercised by one alone. The provision of numerous pairs of organs in the body also affords a great factor of safety in case disease or accident injures or destroys a single organ.

The natural stimulus of the visual receptors is the range of waves in the ether, whose rates of vibration vary from the enormous number of 458 trillion per second in the red to 727 trillion in the violet. By analogy with music this corresponds to one octave of sounds.

The sensitive retina is a network of vast numbers of nerves, receptors and auxiliary structures, which are of microscopic dimensions. The receptors are of two kinds, called "rods" and "cones", the former shaped something like the unsharpened end of a pencil and the latter like the sharpened end. In each retina the number of rods and cones is estimated to be about a hundred million and the nerve fibers about half a million, a smaller number since several rods are attached to a single fiber, while each cone usually has a fiber for itself. The receptors may be roughly likened to the pile on velvet.

In the center of each retina is a very small area, called the "fovea", about the size of the head of a pin, which contains only cones. They are the most important sensory areas in the body, as by them alone we enjoy distinct vision. Through them enters nearly all the information from the external world which reaches consciousness, and by them we are able to read, write and perform with accuracy the greater part of our work. It has been estimated that 87 per cent of all our knowledge is obtained through vision, 11 per cent through hearing, and only 2 per cent through all other senses.

Cones are found only in the central fovea and in a small surrounding zone. Close to this region rods are mingled with cones, while in the extreme periphery only rods are found. A widely accepted theory, known as the "Duplicity Theory", states that the rods are designed for colorless vision in dim light, while the cones are the receptors for bright light and colors. Foveal vision is thus very poor in low illumination and objects are seen indistinctly, or even disappear. Stars that are too faint to be seen by direct vision become visible if the light falls a little to one side of the fovea. The periphery, however, is extremely sensitive to motion. In deep twilight attention may be attracted by a faint light or a moving object viewed by indirect vision; but when one looks directly at the light or object it seems to vanish. Rare cases are known in which complete night blindness occurs when the deepening twilight reaches a sufficiently low intensity.

The action of light on the periphery lowers the sensitivity of the fovea by its reflex action. If, therefore, one looks at a wall through a mailing-tube held at one eye, the other eye being open also, the patch seen through the tube will appear much brighter than the rest of the wall. The action of the tube is to confine the light to the fovea. Even the partly closed hands, held to the eyes like an opera-glass, will restrict the field of vision and thus make it brighter. This device may often be used advantageously in bright daylight when looking at the sky or distant objects.

In addition to the vision of form, man enjoys the perception of colors. When white light, such as that from the sun, is analyzed, it is found to be composed of a mixture of several colors, red, orange, yellow, green, blue, indigo, and violet, which are known as "the spectrum". The rainbow is such a spectrum on a gigantic scale. These colors are the simplest hues possible to obtain. By mixing red and green lights together, however, we obtain various shades of orange and yellow. For this and similar reasons, it becomes evident that all seven are not primary colors. While great numbers of hypotheses of color vision have been devised, the one that has most to commend it was briefly set forth by Dr. Thomas Young in England about the year 1800. According to this theory there are only three simple or fundamental sensations, red, green, and violet, which are necessary and sufficient to account for the production of all possible shades of color.

A color is completely specified by its hue, saturation and brightness. Red and green, for example, are different hues; if they are mixed with white light so that

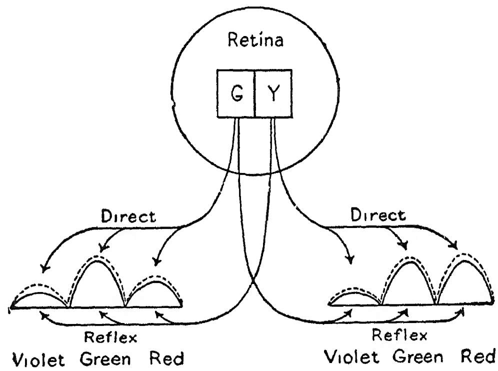
they become pale red and green, they are said to be unsaturated. Colors of all hues and degrees of saturation may be very bright or very dim. All colors, when exceedingly bright or dim, tend to become white. In moonlight or twilight flowers will gradually become colorless, the red being first to disappear and blue the last.

As has been remarked, only three primary color sensations, red, green, and violet, exist in the sense of vision. By stimulating these in various proportions, we obtain the innumerable colors of nature and art. When all three are stimulated equally the sensation of whiteness results. This may happen when the seven spectral colors fall simultaneously upon the eye, when properly selected hues of red, green, and violet are used, when pairs of colors are suitably chosen, and finally when any single color is made of sufficiently high or low intensity. Pairs of colors possessing this property, of which many are found in the spectrum, are called "complementary colors".

Mixing paints or pigments must not be confused with mixing lights. If yellow and blue lights are mixed they produce white, since they are complementary colors. But a mixture of yellow and blue pigments is green. The reason for this is simple. The particles of yellow pigment reflect both yellow and green light, but the yellow so greatly predominates, that green is not noticed. Similarly the blue particles reflect both blue and green light. When mixed, the yellow pigment absorbs the blue light, and the blue paint the yellow. Both colors, therefore, disappear from vision, leaving only green which both pigments reflect.

One peculiarity of vision has baffled every one of the eighty theories of color vision which have yet been proposed. It was discovered by Leonardo da Vinci that when two colors are placed side by side, each modifies the appearance of the other. This is called "simultaneous contrast" or "induction". The same effect is shown when a small piece of light gray paper is placed on a larger surface of colored paper. The gray paper will by contrast appear as if colored by the complementary of the surrounding color. The effect is intensified by placing a piece of very thin translucent tissue paper over the surfaces and viewing them in bright daylight. Blue shadows are sometimes seen on snow because sunlight has really a yellowish hue, and blue is its complementary color.

For two centuries no acceptable explanation of this effect was forthcoming, until the present writer discovered that in vision, as well as in all sensory organs, reflex actions occur analogous to those in muscles. When any color, green, for example, falls on a small area of a retina, afferent nervous impulses ascend to the cortex and excite a sensation of that color. In addition nervous impulses are set free by reflex action which are conducted by efferent nerves to all parts of each retina, which have either an enhancing or an inhibitory effect; that



UNIOCULAR SIMULTANEOUS CONTRAST

is, the receptors in those areas are rendered either more sensitive or less. The sensations complementary to the original color are most affected.

The application of the principle of reflex inductive action to the problem of contrast is easily indicated by the aid of the above diagram. If two contiguous patches of green and yellow upon a neutral gray background be observed, a similar pattern will be formed upon the retina. The *direct* action of the green light stimulus upon the three fundamental sensations red, green and violet is shown at the left of the diagram. Each primary sensation is stimulated to an amount represented by the relative heights of the elevations as shown by the continuous line. The efferent nervous impulses caused by the *reflex* inductive

action of the adjoining yellow light are represented by the arrows acting *under* the elevations, by which their sensitivities are increased. Since experiments show that the visual reflex actions elicited by a color act upon all, but predominantly upon its complementary sensations, the violet and green sensations, which together make blue, which is the complementary of yellow, will be much enhanced in sensitivity. The direct action of the green light will thereby stimulate them more than is normally the case. The degree of stimulation of the enhanced sensations may be denoted by the dotted line in the diagram. Blue will therefore be added to the green, thus modifying that color by mixing it apparently with the complementary of yellow.

Similarly, yellow directly stimulates the three sensations in the manner indicated by the continuous line at the right side of the diagram. The reflex action of green enhances predominantly the complementary red and blue (purple) sensations, of which red is visually the more prominent The yellow therefore stimulates the red sensation more than normally, as indicated by the dotted line, thereby causing yellow to become orange in appearance.

When one looks at a bright light for a few seconds and then closes the eyes or looks at a white wall or paper, after-images become visible for a considerable time. Even looking at the colored cover of a book may suffice to produce the effect. The images are of two kinds, called "positive" and "negative", the former being of the same color as the original light, while the latter form a series of images of many succeeding colors, the first of which is the complementary of the original stimulus The positive after-image is usually much more difficult to observe than the negative. If, just after waking in the morning, when the eyes are extremely sensitive, one looks at a brightly illuminated window and then closes the eyes, a positive image of the window, exactly the same in appearance, will be seen for some seconds The principle of the moving-picture device depends on this persistence of the positive image. Each image persists for a small fraction of a second, and during these intervals the screen is completely darkened while a second picture is put in its place By throwing on the screen from ten to twenty pictures per second the illusion of motion is maintained. No one should look at a very bright electric light or the sun with unprotected eyes, as the intense light may cause a permanent image to appear. Such effects have occurred, and for them no remedy is known.

In addition to the defects of the eye for form vision, it has been found that nearly five per cent of men and less than one per cent of women have defective color vision. They are usually called "color-blind". While ordinarily it is congenital and can never be cured, it sometimes happens temporarily as the result of disease or from excessive use of strong liquors and tobacco As color signals, usually red and green lights, are used at nights on railroads and in steamship navigation, it has become necessary, in the interests of safety, to examine the color vision of all persons who have anything to do with the operation of trains and vessels. Color-blind persons usually cannot distinguish, except by form, red strawberries or cherries from the green leaves, and they also confuse red and green lights.

Since there are three primary sensations, red, green and violet, it is possible for vision to be defective in any one color, in any two colors, and in all three Thus, there are seven classes of color-blindness, all of which have been discovered in various persons. The most rare are the violet and green-violet defectives. Cases of total color-blindness are by no means unusual Such persons are incapable of perceiving colors under any conditions. A flower garden is as colorless to them as the photograph of the garden is to normal vision. Color-blindness is almost certainly due to the excessive predominance of the reflex inhibiting nervous actions by which the sensitivity of the receptors for one or more of the three primary sensations is depressed far below the degree necessary to permit normal responses to color stimulation. The unaffected sensations thus predominate in vision, and the abnormal condition modifies greatly the appearance of many

of the colors. The world of color in nature and art, it must be remembered, exists only in the brain. When the sensations are defective the colors vanish The world without us is devoid of objective color. It is the sensory power of the mind that clothes nature with its glorious garment of colors

The sense of hearing. Why our ears are on opposite sides of the head

The ears, which are the organs of the sense of hearing, are placed on opposite sides of the head in such a position that the auditory axis passing through them is horizontal and at right angles both to the horizontal visual axis and the vertical postural axis of the body. Thus the axes of the two great distance-perceiving organs and posture, form also a set of spatial axes which it is tempting to think constitutes the physical basis for our outlook upon the external world. By their united power man preserves his sense of orientation in the world, arising from the three chief sources of stimulation, gravitation, sound and light, which originate respectively in the earth, the atmosphere and space. With two converging eyes man enjoys a keen perception of space when light is the stimulus. By means of his two ears he can also obtain fair spatial perceptions through their power of determining the directions of sounds. We can therefore scarcely consider the relative positions of these axes to have occurred by accident or by consideration of anatomical symmetry alone.

The ear consists of the familiar external organ which directs sound waves into the auditory canal and thence to the membrane, the tympanum, stretched like a drumhead across it. The aerial vibrations or waves, which are the adequate stimulus for hearing, throw this membrane into vibrations which are communicated to a compound lever consisting of three small bones which, in turn, reproduce the vibrations with diminished amplitude but increased intensity on the inner drum. This membrane covers the opening of the cochlea, a spiral cavity in the side wall of the skull, shaped like a coiled snail-shell, from which it gets its name. The cochlea is filled with a watery fluid in which are situated the terminals of the auditory nerves and their end-organs or receptors. The atmospheric waves, which for the middle note of a piano are about four feet long, are by this succession of structures finally reduced to excessively tiny ripples in the cochlear fluid. The auditory receptors are thus stimulated and excite sensations of sound in the brain. The ripples and nervous impulses faithfully reproduce every physical characteristic of the original sound.

The delicacy of the ear is extraordinary. Motions of molecules of air in contact with the tympanum or outer drum, as small as one one-hundred millionth of an inch, are capable of eliciting a sensation of sound. A membrane of this character cannot be expected to withstand a very strong pressure. Consequently it is sometimes ruptured and hearing rendered defective by the intense sound wave from an explosion, or, in the case of children, by a blow on the ear.

If the sustaining pedal of a piano is depressed so as to raise the dampers from the strings and a person sings loudly in harmony with any note, it will be noticed that the corresponding string will take up the vibrations sympathetically and continue vibrating for some time. The most acceptable theory of hearing regards the receptors in the cochlea as resonators which are similarly set into sympathetic vibration by external waves in the atmosphere. There are 88 strings in the piano; but in the cochlea are found many thousands of receptors, sufficient in number to respond to vibration frequencies from about 16 to about 20,000 per second, the lowest and highest audible tones. While the range of ether waves perceptible to the eye is only a single octave of colors, the ear has a range of about eleven and a half octaves of musical tones.

Sound sensations are of two kinds, noises and musical tones. Noises are regarded as irregular non-periodic vibrations in the air, while musical tones are attributed to perfectly rhythmical vibrations. A musical sound is characterized by three quantities, pitch, intensity or loudness, and quality. Pitch is determined by the number of waves

that strike the ear per second, or, what amounts to the same thing, the wave length. Loudness is determined by the distance the molecules of air move from their normal positions when a wave passes.

When a string is bowed or an organ pipe sounded, it does not give a single tone, but simultaneously emits several tones of higher pitch, which are usually not perceptible. This combination of the fundamental tone and the overtones is the source of musical quality. The number, pitch and intensity of the overtones vary with the character of each musical instrument, and thus account for the differences of quality which they display, and which enable them to be distinguished from each other. Similarly the differences in the vowel sounds produced by the voice are due to different combinations of overtones.

Occasionally people are found who possess a wonderful memory for the absolute pitch of a note. The majority of people, however, can only roughly approximate to this power. But practically all people are capable of accurately distinguishing the ratio which the vibration frequencies of tones bear to each other. The middle note of a piano is formed by 256 vibrations of the string per second. The next white key above has 288 vibrations. The ratio of these two numbers is 288 divided by 256, or 9 to 8. If the pitch of all the keys is evenly raised or lowered, probably no one will notice the change, and it will make no difference in the music. But if the ratios of the notes are changed even in a very slight degree, it is instantly detected and the instrument is judged to be out of tune. The acuity of a highly trained ear is so discriminating that a change of pitch amounting to one one-hundredth of a semitone can be readily detected.

While the eyes are satisfied with colors that merge gradually into each other, the analogous auditory effect in music is most repellent to the ear, which demands definite intervals between successive tones. A succession of tones or a musical scale can be formed that is satisfactory and pleasing to us. It consists of seven tones, or eight if the octave is included, arranged in a series ascending by intervals called "tones" and "semitones". No interval less than a semitone is tolerated in European music. In higher and lower octaves the same intervals are repeated, but with proper changes in pitch.

It might be thought that all peoples of the world possess by nature the same musical scale. This, however, is not the case, for different nations have enjoyed scales of music containing as few as five notes instead of eight, and their ratios were different also from ours. The Arabians derive satisfaction from the employment of quarter-tones in their music.

The methods of combining notes into music have varied widely in different ages. The ancient Greeks, and probably other peoples, employed primitive musical instruments which were played one note at a time. This is still a practice among the Chinese, Indians, Arabs and Turks. It was only in the beginning of the 17th century that chords of music were used to accompany solo singers.

The two-part and four-part vocal music we habitually employ, had its origin in the 11th century in the amusing game of different groups of people singing different songs at the same time, a form of entertainment that still persists. The idea was seized by musicians to write melodies of the same key and rhythm, which gradually developed into our present mode of part singing. At no period in history has music, especially orchestral music, been produced on so magnificent a scale of grandeur and richness as at the present time. It is quite possible, indeed, that this art has now reached its highest attainable development.

The ordinary human voice originates in two elastic membranes stretched across the top of the larynx, or "Adam's apple", and has a range of about two octaves. The most exceptional voice on record possessed a range of three and a half octaves. Songs are usually formed of not more than about twelve notes. Even with these few notes an amazing variety of melodies is possible. In breathing the cords move widely apart and are quiescent. In speaking or singing their inner edges are brought close together and forced by air pressure from the lungs to vibrate as we desire. The feeble effects

of the cords are intensified by the resonating air chambers of the windpipe, throat, mouth and nose. Should the vocal cords touch when vibrating the voice suddenly "breaks". The nasal tone of voice is really not produced by the nose, but by a constricted form of the lower part of the windpipe.

Defects of hearing are to be found analogous to those of the eye. By disease or injury certain tones may not be perceptible to some people, just as a wire for some note in a piano may be broken. Other people may occasionally be found who have "no ear for music", a condition which may parallel total color-blindness. Rare cases are also found who through unusual nerve connections associate colors with tones. The writer was once quite startled at a concert when a friend suddenly called attention to a "rich coffee-colored note".

The power of synthesis and analysis of sounds possessed by the ear is extraordinarily delicate. With full orchestra and chorus it is possible to appreciate the combined effect of a multitude of tones varying greatly in pitch, loudness and quality, and at the same time to distinguish an individual instrument or voice.

The affective or feeling tone accompanying musical sensations is probably much greater than that associated with any other sense. With its endless variety of melodies and harmonies, music has a wonderful power of soothing or exciting the feelings. The minor melodies contribute to sadness and melancholy, the major to joyfulness and exhilaration. Musical instruments of many types in producing martial music are extremely effective in evoking strong emotional reactions. The blare of trumpets and the skirl of bagpipes are capable of exciting feelings that can be stirred perhaps in no other way to an equal degree.

As musical sensations differ from each other in several ways, so noises also differ from each other, and their sensations also have peculiar emotional effects. Noises, indeed, seem to be more natural and fundamental than music. Popular language contains many words which characterize noise stimuli, such as hiss, murmur, sigh, boom, bang, rumble, crash. Each of these is suggestive of a quite appropriate type of emotion which corresponds with it. It is altogether probable that noise stimuli are much more powerful than music in arousing the more primitive emotional reactions and thus determining our behavior.

Each person possesses in his throat a broadcasting device — the voice — which emits a considerable range of waves in the air. We also have two receiving sets — the ears — which are permanently tuned to over 20,000 wave lengths, which include all those formed by every type of voice and musical instrument. By these devices we communicate with each other with the greatest ease. If either the voice or the ear is defective or inoperative, the eyes and hands can be substituted somewhat awkwardly for them. In the case of vision the eyes are receiving stations of vastly greater range, but we have no organ of the body for originating and broadcasting light. Had we such an organ we could extend our range of personal communication to miles instead of yards. Carrying the analogy still farther, if we had broadcasting and receiving apparatus for electric waves within our own bodies, we could then communicate with each other around the world and perhaps across space. Our physical limitations, however, preclude this possibility.

The cutaneous sensations. Touch discrimination not uniform over the body

"The skin", says Sherrington, "is a mosaic of tiny sensorial areas". If an area of the back of the hand is minutely examined by touching it point by point with a sharp piece of metal or wood, it will be found that some places give a sensation of touch, others of cold, and still others of warmth. If the pressure of the point is sufficiently great, certain places will be found to give a sensation of pain. Thus the receptors of at least four sense organs can be distinguished scattered irregularly all over the skin. The skin performs many functions. It provides a covering for the body of uniform color and texture, thereby giving it a presentable appearance. It is a heat insulator, to protect the inner tissues from

danger from varying temperatures. It is also waterproof. When dry it is a fairly good non-conductor of electricity. It is porous, so as to permit excess moisture, with deleterious materials dissolved in it, to be eliminated from the body, and by its evaporation to maintain the organism at a steady temperature. By the action of ultra-violet light, chemical reactions occur in materials contained in the skin which are so important as to be vitally necessary. It contains the numerous receptors of the cutaneous sensations.

The touch receptors are not evenly distributed over the surface of the body, so that tactile discrimination is not uniform. The parts of the body most sensitive for touch are the tip of the tongue, the lips and the finger-tips. The least sensitive are the soles of the feet, the loins and thighs. On the tongue the receptors are so close together that two points one twenty-fifth of an inch apart can be distinguished as separate. On the middle of the back they have to be two and a half inches apart before they can be so distinguished. The delicacy of touch discrimination increases from shoulder to finger-tips, the latter being about twenty-five times as delicate as the former.

The touch receptors are most numerous around the hairs on the skin. Each hair, on the back of the hand, for example, acts as a lever pivoted at the surface, by which the effect of a stimulus is magnified about five times. The sensitivity of the receptors is thus virtually increased by that amount. The long, stiff feelers of a cat may be regarded as magnifiers of the sense of touch analogous to the use of the microscope in vision.

There appear to be at least two sensations of touch; one near the surface of the skin, the superficial sensation, and the other the deep touch. If a very light stimulus that is barely perceptible is used, the reflex actions evoked have the power of making the receptors much more sensitive and preventing fatigue. Work requiring great delicacy of perception should therefore be touched very lightly. This is true in the most delicate parts of musical production, for example, and, in the case of the blind, in lightly touching the raised print used for their reading. Burglars are said to be able to follow the movements of the parts of a combination lock and thus open it by very lightly holding the finger-tips of one hand against it as the other manipulates the dial.

The enhancing or sensitizing reflex actions also render more sensitive the receptors around the spot touched. When the stimulus therefore is moved slowly and lightly across the continually sensitized receptors, a tickling sensation is experienced. This does not occur if the pressure is too great, or if the stimulus moves so rapidly that the nervous impulses have not sufficient time to operate. The same effect is noticed when a part of the skin is itchy The receptors then are oversensitive and relief is obtained by scratching. This action causes the neighboring receptors to be rendered more sensitive, which in turn are relieved by scratching. Thus the itching area spreads over a considerable region. Strongly stimulating one finger depresses its tactual sensitivity, but it renders the other fingers more sensitive than before.

By training, the sensation of touch may be rendered very sensitive, as evidenced in the case of the blind. The famous Helen Keller obtained a high degree of education and a wide knowledge of the external world only by the sense of touch, as she is deaf as well as blind. By the tactual sensation in her fingers she has been able to discover the movements of the throat and lips when people are talking, and then to imitate them herself, and thus has learned to speak with considerable fluency. Blind people, by using a cane, project the sense of touch to its end and thereby judge the degree of roughness or smoothness of their path, and so guide themselves in walking.

Temperature sensations' accuracy largely dependent on area of skin stimulated

As remarked above, there are two temperature sensations, warmth and cold. Each of these has separate receptors and nerves, so that a cold spot cannot produce a sensation of warmth nor a warmth receptor a sensation of cold. They are not, however, independent of each other.

If we place one hand in ice-water and the other in hot water for a short time and then plunge both hands in just warm water, two different judgments are formed. To the cold-adapted hand the warm water appears hot, and to the warmth-adapted hand the same water appears cold. It is thus apparent that the temperature sensations are liable to mislead us.

The area of the skin stimulated has a decided influence on the judgment of temperature. Sometimes we test the temperature of a bath by the fingers. But when the body comes in contact with the water it is found to be far too hot to be comfortable or endurable. Baths for infants should always be tested by a thermometer or by immersing the arm. For an error in judgment in such cases may result in serious injury to the child.

The two kinds of temperature receptors are not equally numerous, the receptors for cold being much more numerous than those for warmth. The latter also are much more sluggish in their response.

There is a temperature "after-image" like that in vision. If a coin is placed on ice, then dried and pressed for a few seconds against the forehead, the after-effect is so vivid when the coin is removed that a blindfolded person will persistently shake the head to detach it. This peculiar trick is often played for amusement at children's parties.

Pain, the great protective sense of the body and the widest spread

The receptors for pain are scattered all over the surface of the body, both inner and outer, and are also found in the joints and within the tissues. Pain is the most extensive of all our senses. The receptors are not specialized, but consist of the naked nerve endings. Thus they are excited by intense stimulation of every type. Heavy pressure, intense heat and cold, chemicals, — like strong acids and alkalies, — electric currents of sufficient strength, etc., are all capable of stimulating this sensation. Pain, however, results only when the stimulus is sufficiently intense to be dangerous to the organism. It is evidently, therefore, the great protective sense of the body. In consciousness, too, a sensation of pain immediately dominates all others. It insists upon occupying the first place in attention. Thus the cause of pain is immediately sought for and, if possible, removed before the organism becomes injured. If we had no pain sensation, as sometimes we are strongly tempted to wish, the hand might be destroyed by burning or scalding before we happened to notice the danger. In the eye there are no touch receptors, but those of pain are numerous and close to the surface. A rough particle, such as a cinder, will therefore cause the most intense pain. In the joints of the body the pain receptors are quiescent as long as the lubricating material is abundant, so that smooth working is assured. But if the joints become dry and inflamed, as in rheumatism, the receptors become very responsive, causing the most exquisite pain.

Sometimes a pain sensation which originates in one part of the body may, by interaction of the nerves, be felt in another. This is called "referred pain". The origin of many headaches, for example, is in reality in some other organ, such as the eyes or stomach.

It is one of the greatest triumphs of modern medicine that certain drugs can be safely administered as anæsthetics for short intervals of time. Thus operations, which formerly were accompanied by excessive pain amounting often to intense agony, can now be performed with a minimum degree of distress and discomfort. This is a privilege of ours not yet enjoyed by the bulk of equally suffering humanity; and it ought to be one of the great aims of the more advanced nations to spread such knowledge over the world, so that no person would be beyond the possibility of obtaining such marvelous relief.

Taste, the result of stimulating four sensations, bitter, sour, salt, and sweet

The receptors for the sense of taste, which in some fishes lie on the skin and fins, are confined in man chiefly to the upper surface of the tongue. While every part of this organ can distinguish all tastes, the separate sensations are concentrated chiefly in different areas, bitter at the back of the

tongue, sweet at the tip and sour at the sides. The receptors are barrel-shaped organs of microscopic size, and are known as "taste buds". The number of receptors varies enormously in different animals. They are fewest in birds, and of these parrots have the most. In the bat there are about 800, in the squirrel 5,000, in the hare and man 9,000, in sheep 10,000, in the pig and goat 15,000, and 35,000 in the ox.

The almost numberless tastes we experience are the result of stimulating only four fundamental sensations, bitter, sour, salt, and sweet. Their sensitivity also follows this order, since a far smaller quantity of a bitter substance, like quinine, is required to excite that sensation than of sugar to elicit the sensation of sweetness.

The sense of taste is decidedly analogous to vision in many ways. A weak solution, like a feeble light, depresses sensitivity, so that we like all tastes to be quite decided. Tastes also can neutralize each other, like complementary colors. It is possible to obtain a mixture of sugar and quinine solutions that is perfectly tasteless. Everyone is aware of the fact that sugar neutralizes the bitter taste of coffee.

There seem to be no persons who in taste are analogous to the color-blind. While in certain types of brain disease one or more tastes may disappear, in no case does a healthy person seem to have been found devoid of any of the four taste sensations.

The sensations are not independent of one another. While one sensation is being fatigued or depressed in sensitivity, the reflex actions evoked may enhance the sensitivity of another. Thus, after stimulating the tongue with an acid solution like vinegar, or with some salts, the sweet sensation becomes so enhanced that distilled water, ordinarily tasteless, becomes apparently sweet. A rare Australian plant contains an acid, gymnemic acid, which, when applied to the tongue, inhibits for a short time the sweet taste, while cocaine inhibits the bitter sensation.

In arranging a menu for dinner, for example, it is desirable to select foods that possess a variety of qualities, so that when one sensation becomes fatigued the others are enhanced. Thus we use sour pickles, sweet jellies, salted nuts, olives, and bitter coffee. By a proper succession of flavors the sensations may be maintained in a state of great vivacity. But if one taste alone is chiefly stimulated, the dinner becomes highly monotonous.

Some of so-called taste sensations are really sensations of pain. The "tastes" of pepper and mustard belong to that class. These are valuable chiefly for their stimulating effect upon the organs secreting the digestive fluids. With foods, sensations of warmth and cold also are excited. Many tastes are in reality odors. This is readily shown by the fact that when the sense of smell is inhibited by a cold, many foods also lose their customary flavor. The sense of taste is susceptible of a high degree of refinement. Professional tea-tasters are able to detect the minutest differences in teas, and thus are able to produce the most delicate blends.

The taste sensations form one of the finest groups of sensations we possess, but they are easily abused and degraded. Their continual gratification by excessive eating and drinking leads to the necessity of using still more highly seasoned viands, with resulting degeneration of more than the taste sensations.

A well-ordered dinner seems to involve most of the senses. Vision is gratified by arrangement and colors; the posture, muscle sense, the sensations of warmth, cold and pain, the sensations of smell, hunger, appetite and thirst, the sensations of taste, and the final sensations of comfort and repletion, are all involved. The sense of hearing is also stimulated by music and conversation.

Smell, a sense stimulated by quick intakes of air, like sniffing a flower

Closely allied to taste is the sense of smell. The olfactory receptors are situated in one of the upper chambers of the nose, well out of the way of direct action of the air during respiration. They are located in a sort of backwater, or eddy, in the air current. By this means the receptors, which are like delicate hairs embedded in a rather viscous liquid material, are prevented from becoming dry and unre-

sponsive. The stimulus for smell consists of vapors and gases, and also streams of small particles floating in the air. These enter the fluid mass around the receptors and so stimulate them by chemical action. If too much material enters the liquid, it becomes overloaded and the receptors cannot respond until it becomes free again. Thus powerful odors quickly fatigue the receptors.

The sense of smell is not stimulated so much by steady breathing as it is by drawing in the air in quick inspirations. Smelling a flower is usually done by sniffing its odor. This action no doubt causes the air in the nasal passages to form miniature whirlpools and so compel extra amounts to enter the olfactory chamber.

Strong odors, such as those in badly ventilated rooms, quickly and fortunately fatigue the receptors, so that in a few minutes a repellent atmosphere becomes unnoticeable; but faint odors enhance the sensitivity of the receptors and thus can be detected for long periods of time. In man the sense of smell is not so highly developed as in many of the lower animals, such as the dog; for in these animals it is of such wonderful sensitivity that it becomes of more value than vision itself. A bloodhound can follow the extraordinarily faint odor of a trail even several hours after it has been made.

The sense of smell is one of the distance receptors, like vision and hearing. The sensation is also projected to the object and is deemed an objective property of it. While there are many kinds of pleasant and unpleasant odors, all attempts at classification on the basis of a few fundamental sensations, like those of taste and vision, have failed.

Hunger, appetite and thirst—three senses about which little is known

This important group of sensations must be classified as senses of independent character, though the first two usually appear to be different aspects of the same sense. Appetite, however, is mild, pleasant and agreeable in character, whereas hunger is both disagreeable and, in advanced stages, painful.

Appetite is certainly related to taste and smell, and is stimulated by the operation of these senses.

Hunger is of a different nature and appears to be due to the collapse of the empty stomach, the walls of which then exert a pressure against each other. Hunger is satisfied by volume of food, not merely by gratification of taste. Hunger may compel a man to eat most repellent material, which the appetite would normally refuse with disgust. On the other hand, when hunger is perfectly satisfied, the appetite may be stimulated over and over again by the attractive sight and odor of tempting viands. The sense of hunger seems to disappear after a few days' abstinence from food. Thus periods of fasting for forty days become endurable, and even a much longer period than this has been found to be possible.

The sense of thirst, which is located in or referred to the throat, is even more imperious than hunger, and cannot be endured beyond a very few days. The receptors for this sense are unknown, and the nature of its stimulation can only be partially conjectured.

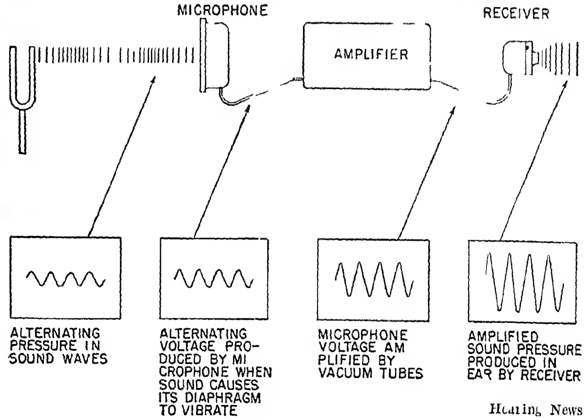
These senses, as well as several others of a vague and obscure nature, are of such a character that little is known of them. All are concerned with vital functions of the body; and while their sensations are ordinarily quiescent, they may easily become so assertive as to dominate every power of the organism.

The world of sensation, is, as we have seen, of marvelous variety and complexity. In health, the pleasures of sensation become so alluring that the temptation to abandon oneself to their gratification becomes very great, and in many cases almost irresistible. But in time the sensory world becomes dull and the pleasures associated therewith lose much of their attraction; "desire shall fail" and physical life becomes increasingly monotonous. Hence the necessity, as St. Paul says, of "keeping under the body", of cultivating pleasures associated with the intellectual and spiritual parts of our nature, which afford the highest forms of pleasure at all times; which also alone are permanent.

NEW EARS FOR THE HARD OF HEARING

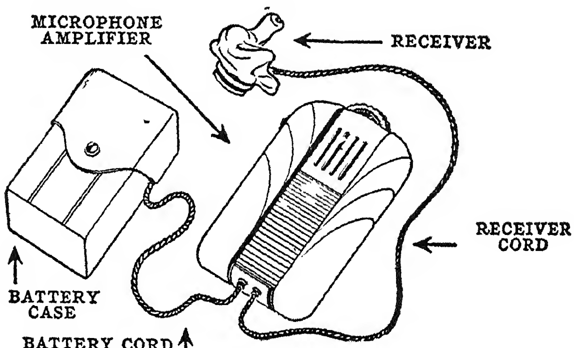
Sonotone Corporation

The hearing aid shown above, like most modern ones, is an electronic device It has three parts, which are connected by wires The receiver fits the outer ear closely extending into the channel The amplifier which is worn on the chest picks up sound-waves and transforms them electrically A small case contains batteries, these supply the power, which can be turned on or off at will With electronic hearing aids, those who are hard of hearing can generally carry on the normal activities of life



Hearing News

This diagram shows how the electronic hearing aid works



The three compact units of the electronic hearing aid

N Y League for the Hard of Hearing

A class in lip-reading Ability to read lips is helpful even to those provided with hearing aids.